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Science Focus

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Sleep deprivation:
CAN IT CURE DEPRESSION?

Why it's OK to
SKIP BREAKFAST

Fixing medicine's
DEADLY GENDER PROBLEM

NEW SECRETS OF THE **SUPERMASSIVE BLACK HOLE**



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Blue Planet II

Did the series
help the natural
world?

Dementia

The research
giving patients
a new voice

Music

Why heavy
metal is
good for you

Transgender Athletes

The science behind
the debate

Genome

How poverty
can harm
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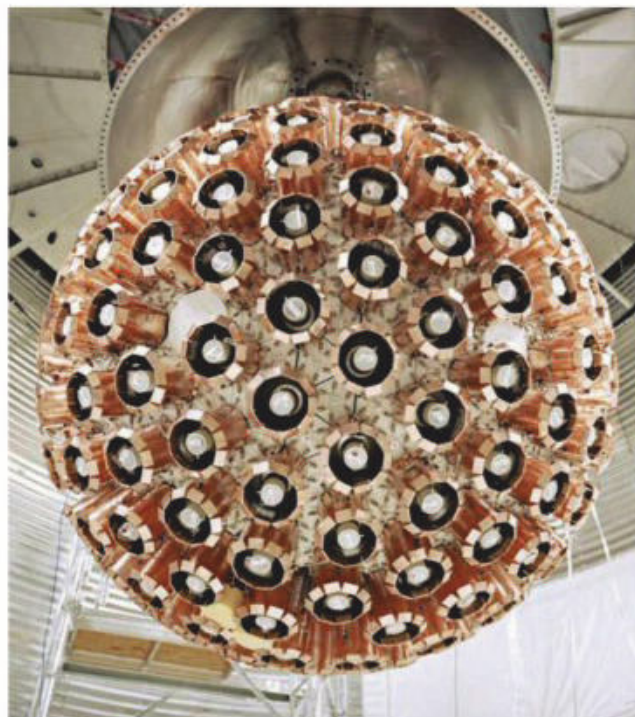
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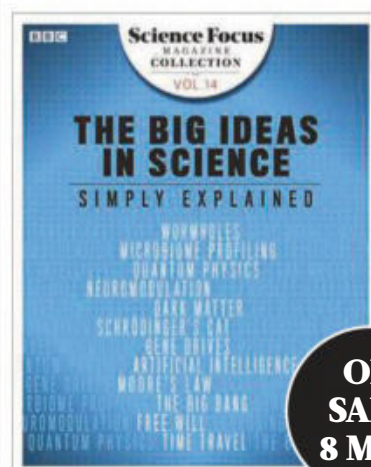
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Can't wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied.

sciencefocus.com

**SPECIAL ISSUE**

**ON SALE
8 MAY**

**BIG IDEAS IN SCIENCE
SIMPLY EXPLAINED**

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Stephen W Tayler on the Flare® PRO 2HD
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→ Meet the echidna, one of the world's oddest creatures... → p83

FROM THE EDITOR



In a galaxy far, far away, there's a place beyond the reach of science (no, not Endor), a place where the way we perceive and even think about the Universe falls apart (no, really, not Endor). I am, of course, talking about a supermassive black hole. A cosmic monster that's crammed 6.5 billion times more matter than our Sun contains into an area so small, it doesn't actually have spatial dimensions. The consequence of this cosmic crunch is that nothing, not even light, can escape its pull. And yet, last month, a global team of scientists announced they had managed to capture an image of this black hole at the heart of the galaxy M87.

They had gathered and weaved together light that left the outer reaches of this black hole some 55 million years ago to create the image we all saw last month. To put that into perspective, the image we see is of the black hole at a time just after dinosaurs ruled the Earth. After its long journey, the light was so faint that a telescope nearly the size of our planet was required to collect it – so we built one, figuratively speaking. It's a mind-boggling feat of human ingenuity and testament to the power of human curiosity. Enjoy the full story on p48.

Daniel Bennett

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...



Podcast

Ahead of the 50th anniversary of the Moon landings, Kevin Fong digs into the science that got us there.

bbc.co.uk/sounds

iPlayer

Go behind the scenes of the Event Horizon Telescope, the project which created that black hole image, in *How To See A Black Hole: The Universe's Greatest Mystery* bit.ly/blackholepic



TV

During Mental Health Awareness week, Nadiya Hussain investigates anxiety, David Harewood shares his experience of psychosis and Alistair Campbell talks about living with depression.

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JHENI OSMAN

Can staying in work help people with dementia? We sent former *Science Focus* editor Jheni to a pop up restaurant in Bristol that's aiming to find out. → p66



SIMON CROMPTON

Walk into any pharmacy and you'll be given the same drugs, regardless of sex. Health writer Simon asks whether it's time for change. → p72



DAVID VEALE

On the eve of Mental Health Awareness week we met Prof David Veale, who's investigating a surprising new treatment for depression: sleep deprivation. → p58



MICHAEL MOSLEY

For those of you who skip breakfast, *Trust Me, I'm A Doctor's* Michael Mosley has some good news – it doesn't really matter, as long as you enjoy a healthy diet. → p63

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EYE OPENER

Hang in there

**YASUNI NATIONAL PARK,
ECUADOR**

Having a bad day? Then spare a thought for this caterpillar. It's been eaten from the inside out by braconid wasp larvae, seen here pupating inside their cocoons, dangling from the caterpillar via silk threads.

The parasitic wasps use needle-like 'ovipositors' at the base of their abdomen to pierce their victim – usually a caterpillar – and deposit eggs inside the body. Once the eggs hatch, the larvae use their host as food until they break through and begin the process of spinning their cocoons and pupating into adult wasps. Incredibly, this caterpillar was still alive when the photo was taken. Apparently, some wasps keep the host alive on purpose, to deter predators from attacking the cocoons.

LUCAS BUSTAMANTE

VISIT US FOR MORE AMAZING IMAGES:

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EYE OPENER

Sonic boom

CALIFORNIA, USA

The shock waves of two supersonic aircraft are seen meeting in this image, captured for the first time by NASA. As a plane flies, it knocks air molecules out of its path, producing sound waves. When the plane hits the speed of sound, the emanating sound waves are compressed until they merge to form a shock wave. The composite image was taken using a technique known as 'Schlieren photography'. A third plane flying above shone a beam of parallel light rays onto the supersonic aircraft below, highlighting variations in air density. "We never dreamt that it would be this clear, this beautiful," said JT Heineck, physical scientist at NASA's Ames Research Center. NASA is studying how shock waves interact as part of the development of quiet supersonic flight.

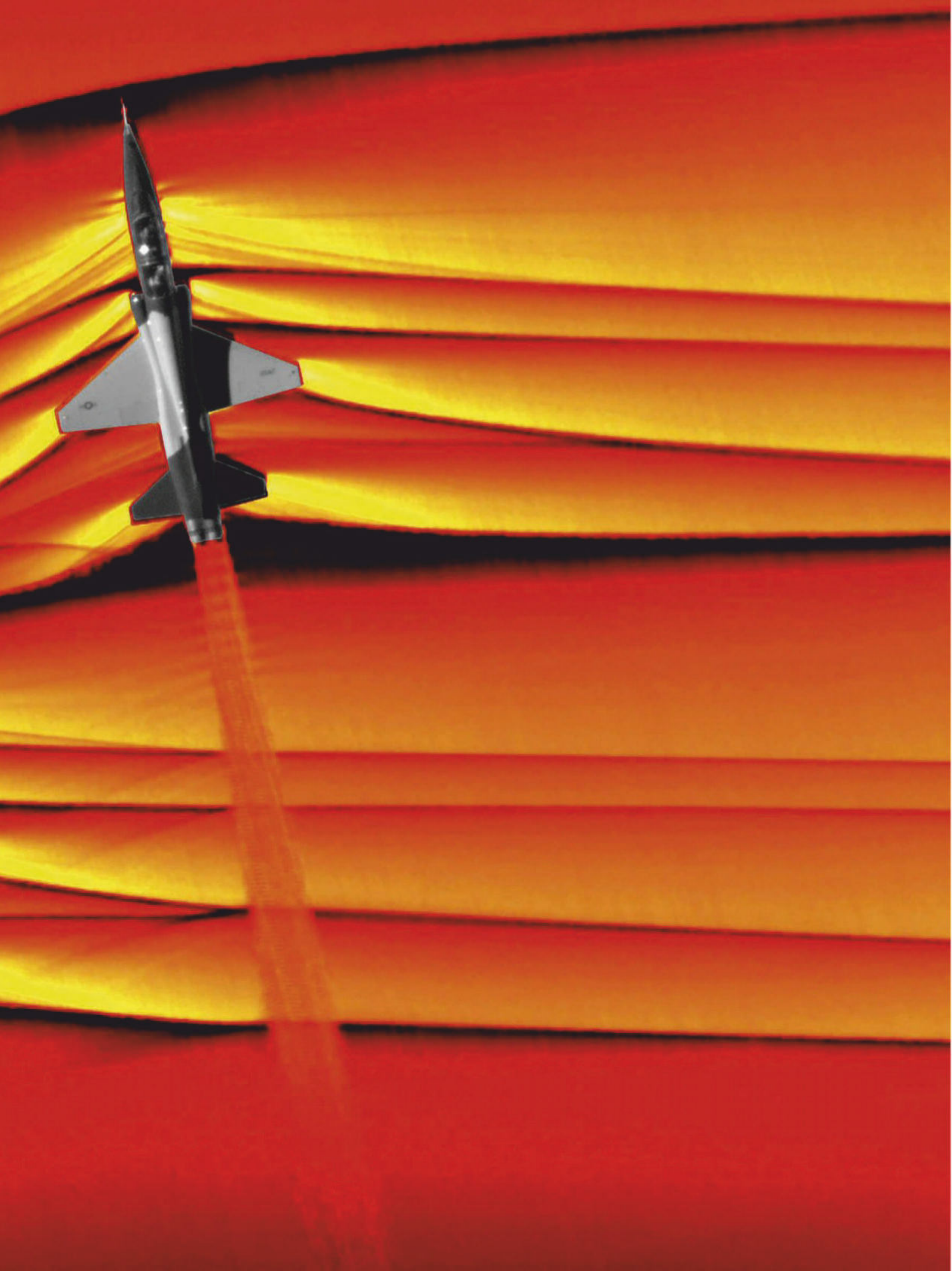
NASA

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND BBC SCIENCE FOCUS

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LETTER OF THE MONTH

New subscriber

I have long been a subscriber to *New Scientist*, but over the last few years it had become increasingly political. I fancied a change and last week I picked up a copy of *Science Focus*. This magazine has been an absolute pleasure to read from cover to cover. Something that really stood out to me was how balanced and accurate your articles are. In the *Tune Up Your Brain* section you acknowledge the reason why there may not be much evidence supporting the use of supplements. I myself would not take supplements without a strong evidence base, but as

a scientist I recognise the value of unbiased and accurate reporting so for me you're ticking all the right boxes. I also happen to have a keen research interest in the placebo effect and I was so happy to see how accurately you managed to get the complex discussion across. Thank you for producing an excellent magazine I will definitely be subscribing to future issues.

Tamsin Nicholson, via email

EDITOR: Ahh, thanks for your kind words, Tamsin, we aim to please! We hope you enjoy the articles in this month's issue just as much.



WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a bundle of gifts from **Rex London** worth over £50, including the tumbler, lunchbox, travel mug, portable USB charger and washbag pictured here, plus a biscuit barrel. All the items come from Rex's wild birds and periodic table ranges you can see the full catalogue at rexlondon.com

WORTH OVER £50



The future's bright

At Saint Francis Xavier School we're very passionate about the ecosystem, and we have been awarded a Green Flag accolade, which is given to schools who have achieved a high standard in creating a better ecological environment. Since then we are trying to become a plastic free school. As part of that aim we are trying to spread the word to the wider community.

As a school we try not to buy single use plastic bags and drinks bottles; as an alternative we have used cans which we crush and sell to fund our LED lights. An eco team member buys *BBC Science Focus* every month and has noticed that you wrap it in a plastic bag. She's tried to help the environment by not buying things in plastic bags, but it's not possible to get hold of your magazine without it being in a plastic bag.

As an alternative to plastic you could use a potato starch bag, which biodegrades and doesn't impact the environment. We do hope you change the packaging of your magazine and we would really appreciate it if you could respond.

The Eco-Team, Saint Francis Xavier School

It's brilliant that your school has an eco-team and that you are keen to reduce your environmental impact, and thank you for your comments regarding the bags we use to package the magazine. This is an issue we also take very seriously. We have dedicated project teams, both within our company and at industry level, working on ways to further improve our approach to sustainability and recycling.

ON TWITTER



@JamColley

I've accidentally set up push notifications for the BBC science magazine, and it's like being followed about by an inquisitive but annoying child
 705 comments
 29K retweets
 144K likes



@rim246

I'm signing up.



@DrSmokyFurby

Sold! Just started following your Q&A



@josh_m

Now if only that were true for our local ABC who seems to like sending push notifications for random celebrity deaths at 5am



@BennettDan

Hmmm... is there a word for feeling proud and ashamed all at once?



“THE PROBLEM WITH THE TERM ‘DEPRESSION’ IS THAT IT’S VERY HETEROGENEOUS. THERE ARE MANY DIFFERENT TYPES OF DEPRESSION, AND LOTS OF DIFFERENT SYMPTOMS”

DAVID VEALE, p58

Our subscribers receive their copy in a bag in order to protect it during the postage process, but we know this is not ideal. However, the plastic is recyclable and we are putting a bigger label on it from the next issue to make sure people are aware of this.

We are also researching different techniques to reduce our plastic usage. We are currently running a trial where subscribers receive their magazine unwrapped with just a printed label for their address.

There are various other packaging options that we are investigating as well. It’s a very complex area, as we’re sure you will be able to appreciate, and we’re keen to ensure that when we make a long-term decision, it takes into account all the different factors – such as ease of recycling, emissions and weight – that can influence our carbon footprint, so that it will help us meet our environmental goals.

However, we are hopeful that we should have a better option than plastic very soon.

Alice Lipscombe-Southwell,
production editor

From pole to pole

Regarding Ian Newton’s question in *Conversation* (April, p14) about why we are taught that the north pole of a magnet or compass points to the north magnetic pole of the Earth which is in the northern hemisphere... it was precisely this question that got me interested in all sciences just before leaving school at the age of 14 in 1946. I remember that thought I was pretty clever having thought of this question, when none of my class mates

We were in a time capsule!

@EllaMclellan

My daughter recently opened her time capsule, made in the year she was born. It included a copy of the Dec 1998 *Focus* magazine @sciencefocus. A fascinating read, although some of the predictions were rather “interesting”!

@sciencefocus

That’s a brilliant find. We wonder how close we came with some of our other predictions?



@EllaMclellan

Well, you were not far off with the whole phone, internet, satellite connected to your car stuff. But as you can see, an early navigation device would have set anyone back a cool £1,500 plus fitting.

“IS IT NOT TIME WE MADE AN EXAMPLE OF A FEW ANTI-VAXXERS?”

had done so! I think this demonstrates that (at least some) science teaching over the last 70 years still leaves a lot to be desired!

David Wilkinson (87),
Ex-UN FE advisor, Oxford

Time for action

I’m writing in response to your article regarding the growing anti vaccine movement in *Reality Check* (April, p38).

As you point out in the article, when people refuse to vaccinate

their children, they put not only their own offspring at risk, but also other people’s. To my mind, there is no excuse for this kind of behaviour! Everyone has a right to their opinions, of course, but putting lives at risk – particularly when to do so flies in the face of all available scientific evidence – is grossly irresponsible.

There are already cases in the UK of people being imprisoned for knowingly spreading the HIV virus. Is it not time we made an example of a few anti vaxxers?

Peter Thorpe, Chelmsford

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Naturally cleansing

Discover the science and benefits of forest bathing with the Woodland Trust

While the Japanese art of forest bathing has been around for decades, it has only recently reached British woodlands. Also known as shinrin-yoku (which literally means 'forest shower'), forest bathing is the art of immersing yourself in the sights, sounds, smells and textures of the woodland ecosystem.

Scientific studies have shown that practising forest bathing brings a whole host of health benefits*. Aside from the usual refreshed feeling a walk in the woods might leave you with, forest bathing delves much deeper, and can have positive impacts on both your mental and physical health.

THE BENEFITS OF FOREST BATHING

Forest bathing is said to lower blood pressure, boost your immune system and even combat anxiety, depression and trauma. It can help aid restful sleep, increase positivity and reduce stress, anger and fatigue. It's also a great way to unplug, step away from the hustle and bustle of everyday life and be at one with nature.

Dr Qing Li, associate professor at the Nippon Medical School in Tokyo, suggests the reason forest bathing is so beneficial is predominantly down to tree oils called phytoncides. Trees emit these oils and, when inhaled, are said to boost your immune system. "The effects can last up to 30 days, so even forest bathing once a month is worthwhile," Li says.

HOW TO GET THE MOST OUT OF FOREST BATHING

When forest bathing, it's vital to embrace all aspects of the woodland. Admire the dappled sunlight as it dances before your eyes. Breathe in the rich forest air. Listen to the sounds of the woodland, from the crunch of leaves and springy earth beneath your feet to the sweet twittering of birdsong around you.

Be tactile, too – reach out and touch the trees, feel the texture of their bark beneath your fingertips and acknowledge their beauty. You could even take your shoes off, if it's dry. The more you immerse yourself in the woodland, the more benefits you will reap.

Li says: "It's important to engage all five senses: take in the aromas of the woods, the sound of the birds, the beautiful scenery, the taste of the fresh air and your sense of touch – literally feel the trees. Walk slowly, noticing what's going on around you. Breathing is key too: deeply through your nose and out through your mouth."

So, the next time you venture into a wood, why not try forest bathing and see how it makes you feel?

The Woodland Trust has over 1,000 woods across the UK, just waiting to be discovered – they're ideal locations for a spot of forest bathing. All of the woods are free to visit and yours to explore.

*Psychological effects of forest environments on healthy adults: Shinrin-yoku as a possible method of stress reduction, 2007. The physiological effects of Shinrin-yoku: evidence from field experiments in 24 forests across Japan, 2010. Physiological effects of Shinrin-yoku using salivary cortisol and cerebral activity as indicators, 2007.

WOODLAND WELLNESS

On 4 June join Woodland Trust's Stuart Dainton, forest bathing practitioner Faith Douglas and other high profile speakers at The Cheltenham Science Festival, as they discuss the relationship between nature and physical and mental health, and why we should make the most of the spaces around us. You'll then be guided through the ancient process of forest bathing in a taster session in local woodland.

Buy tickets now at cheltenhamfestivals.com

Help the Woodland Trust to protect and create the woods you love.
Visit woodlandtrust.org.uk/GWjoin to begin your woodland adventure



BEAR-FACED CHEEK

Why playful sun bears are natural impressionists **p21**

ROAD WARS

Drivers vs cyclists: it's worse than you think **p17**

LIFE ON MARS

Which 3D printed habitat will win NASA's contest? **p28**

PLUS HOLY MOLY!

The full story behind *that* black hole picture **p48**

DISCOVERIES



MDMA could help treat post-traumatic stress disorder

The psychoactive ingredient in ecstasy may strengthen the patient-therapist bond

The psychedelic drug MDMA can reopen a window to a 'critical period' in the brain's development when it was first learning social behaviours, researchers at Johns Hopkins University have found. Harnessing this effect may make it helpful for treating people with post-traumatic stress disorder (PTSD) and other psychiatric disorders, they say.

Critical periods are stages of an organism's lifespan during which the nervous system is particularly sensitive to picking up new skills or behaviours. For example, there's a critical period for language acquisition which typically lasts for

Cancer dogs Dogs are your lungs' best friend **p24** **Synthetic alcohol** High times without the hangovers? **p25**
Do the slim and vac! Does household dust play a role in obesity? **p20**

News in brief

LIFE FLYING BY? BLAME YOUR BRAIN

Feel like time's speeding up as you get older? According to Prof Adrian Bejan, a mechanical engineer at Duke University, it's thanks to the way our brain processes images. As we age, our neurons mature into larger, more complex networks and signals take longer to travel along them, so we obtain and process images at a slower rate. We therefore see fewer new images in the same amount of time, which makes it feel as though time is passing more quickly.



► years of a person's life. After this period is over, it becomes more difficult to learn how to speak a new language fluently. Similar critical periods exist for the development of vision, touch and movement.

"We wanted to know if there was a critical period for learning social reward behaviours, and if so, could we reopen it using MDMA, since this drug is well-known to have pro-social effects?" said research leader Dr Gül Dölen, assistant professor of neuroscience.

To find out, the team placed a group of mice together in a enclosure filled with a specific type of bedding for 24 hours. Next, they separated the mice and placed them in individual enclosures filled with a different type of bedding for 24 hours – this taught the mice to associate the two types of bedding with either isolation or companionship. They then allowed the mice to wander between enclosures with the two types of bedding and tracked how long they spent in each – the more time the mice spent in the bedding linked to their companions, the more they were working to deepen their social bonds.

By studying the mice as they matured,

they found that mice exhibit far less of this social bonding behaviour after hitting puberty. However, when they gave adult mice a dose of MDMA, they found that most of them began to act like juveniles again, once more forming a positive association between social interactions and their bedding. This suggests that the MDMA was able to revert the mice's brains to a critical period when they were learning how to establish social bonds.

"As we develop new MDMA-based therapies, or determine when to give these therapies, it's critical to know the biological mechanism on which they act," said Dölen. "This suggests that we've reopened a critical period in mice, giving them the ability to learn social reward behaviours at a time when they are less inclined to engage in these behaviours."

According to Dölen, reopening the critical period for social reward behaviour may also have implications for treating psychiatric conditions such as PTSD, as a strong bond between patient and psychotherapist is known to be important for successful treatment.

For the latest science news, visit sciencefocus.com



WARNING

MDMA is a Class A drug according to UK law. Anyone caught in possession of such substances will face up to seven years in prison, an unlimited fine, or both.

Information and support for those affected by substance abuse problems can be found at bit.ly/drug_support



SPECIALISED BRAIN CELLS COULD PREVENT OVEREATING

Rockefeller University scientists have identified brain cells in mice that, when activated, may prevent overeating. The cells, called hD2R neurons, also play a role in memory and are part

of a larger brain network that monitors eating. "They appear to make eating less rewarding, tuning the animal's relationship to food," said researcher Estefania Azevedo.



POOR SLEEPERS

Do you struggle to get even 40 winks? Perhaps the Phyjama – a set of smart bedclothes designed at the University of Massachusetts – can help. Monitoring our heartbeats, movements and sleeping positions over time can help poor sleepers to get more shut-eye, say the researchers.

MUSICIANS

Those who've spent years mastering an instrument have better concentration, says a new study in Chile. The experiment found that 18 pianists could focus their minds more quickly and for longer than 18 non-musicians.



Four wheels good, two wheels bad? Other road users don't have much time for cyclists

PSYCHOLOGY

More than half of motorists view cyclists as subhuman

Strong negative opinions lead to deliberate acts of aggression

From so-called MAMILs (middle-aged men in Lycra) to fixie-riding hipsters, cyclists seem to suffer from more negative stereotyping than other road users. But a study by Australian researchers has found that some motorists take things further, disliking cyclists so intensely that they view them as not being completely human.

The study involved over 400 participants from three states, some of whom had ridden a bicycle in the last year and some hadn't. Participants were shown either the iconic evolution of ape to man image or an adaptation of it, showing the stages of evolution from cockroach to human, that was designed for the study because 'cockroach' and 'mozzie' are insults commonly hurled at Australian cyclists. They were then asked to rate how 'human'

they believed cyclists to be on the scale, from 0 (cockroach or ape) to 100 (human).

On both scales, 55 per cent of people in the group who hadn't ridden a bike in the last year rated cyclists as not being fully human. What's more, 17 per cent said they had used their car to deliberately block a cyclist, 11 per cent said they had deliberately driven close to a cyclist and 9 per cent said they had used their car to cut off a cyclist.

"When you don't think someone is 'fully human', it's easier to justify hatred or aggression towards them," said research lead Dr Alexa Delbosc. "And if cyclists feel dehumanised by other road users, they may be more likely to act out against motorists, further fuelling negative perceptions. Ultimately we want to understand this process so we can put a stop to the abuse."

Good month

Bad month

THE SWEET-TOOTHED

Reaching for your favourite sweet treat is unlikely to improve your mood. Using data from almost 1,300 adults over 31 studies, University of Warwick researchers concluded that the idea of a 'sugar rush' is a myth, regardless of the type or amount of sugar.

"FEMMES FATALES"

Male-dominated businesses aren't always female-friendly – and according to a study at Washington State University, women deemed attractive face specific problems, being judged as less truthful and trustworthy by both male and female colleagues.



They did what?

Robots enable fish and bees to 'talk' to each other

WHAT DID THEY DO?

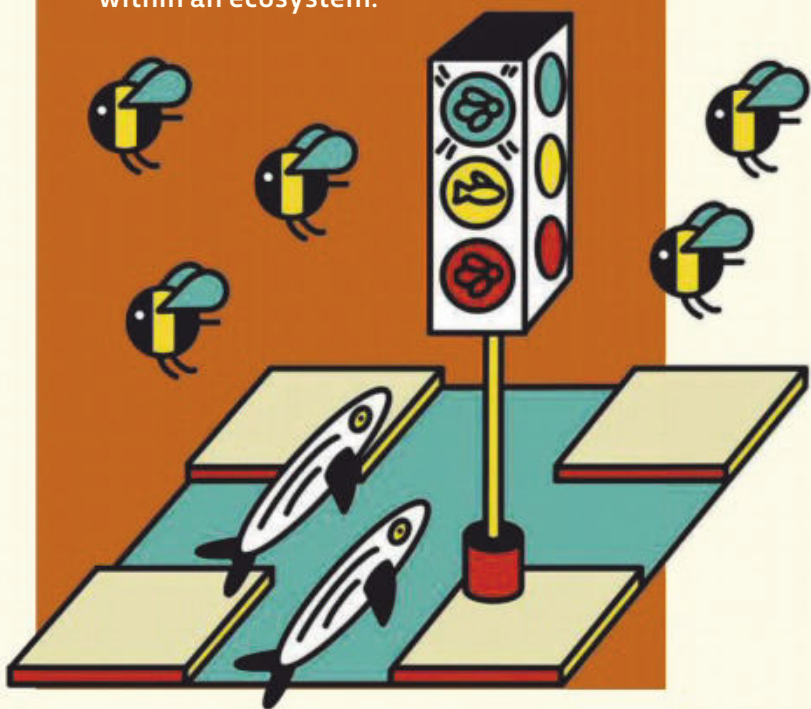
A team from the Swiss Federal Institute of Technology Lausanne created robots that coordinate the actions of a group of bees and a group of fish.

HOW DID THEY DO THAT?

They placed a robot fish inside a tank with a shoal of zebra fish, and a number of robot terminals inside an enclosure populated with bees. Each of the robots emitted signals such as colour variations, vibrations and subtle movements known to be understandable by the animals. The robots then responded in real time to the animals' movements and exchanged that information with each other in an attempt to coordinate their activity.

WHAT DID THEY FIND?

For the first 25 minutes the conversation was chaotic but eventually the animals came to a consensus – all of the fish started swimming anticlockwise around the tank and all of the bees swarmed around one specific terminal. The research could allow engineers to create ways for robots to translate biological signals, or may allow us to understand how species interact within an ecosystem.

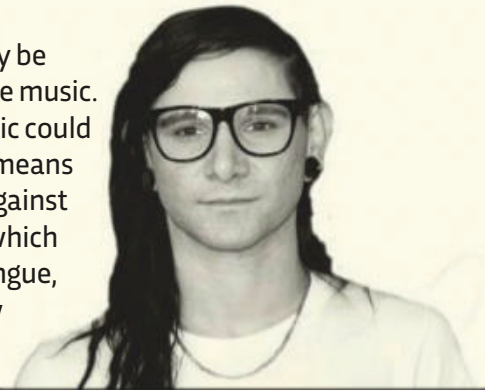


DUBSTEP REPELS MOSQUITOES

Skrillex's music can protect against mosquito bites, according to a new study. Female *Aedes aegypti* mosquitoes that were played music by Skrillex attacked later and far less frequently. They also had sex less often when the music was playing.

The buzzing of females' wings allows males to identify them, and the scientists

believe this may be disrupted by the music. They hope music could provide a new means of protection against *Aedes aegypti*, which spreads the dengue, Zika and yellow fever viruses.



MEDICINE

'Molecular surgery' gives pain-free operations

For some procedures, at least, the surgeon's scalpel and stitches could soon be a thing of the past

Fear the surgeon's knife? A new technique could banish the scalpel for good – at least for certain operations. Dubbed 'molecular surgery', the tech has been developed for procedures that involve reshaping tissue.

Usually, this kind of surgery involves cutting and suturing, which is painful and leaves scars. Now, researchers at Occidental College in Los Angeles and the University of California have reshaped tissue with no incisions or scarring, and minimal recovery time. It could be useful for cosmetic surgery, but also for problems such as immobile joints and poor eyesight.

"We envision this new technique as a low-cost procedure done under local anaesthesia," said Dr Michael Hill, one of the project's principal investigators. "The whole process would take about five minutes."

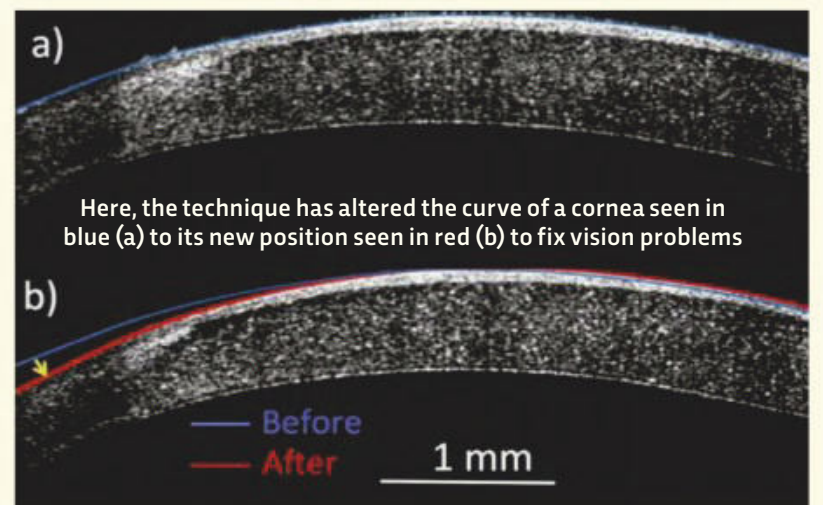
So far, the researchers have focused on cartilage, which is a tough connective tissue found throughout the body. By passing electric currents through the cartilage, the scientists found that they could make it flexible, while avoiding damage to the tissue.

The technique works by 'electrolysing' the

water inside the cartilage – splitting water molecules into hydrogen and oxygen gases. The creation of charged hydrogen atoms alters the electric charge inside the cartilage in such a way that the tissue becomes malleable as a result.

The team tested their process on a rabbit, using a 3D-printed mould to bend one of its ears into a new shape. By inserting tiny 'microneedle' electrodes into the ear and pulsing a current through it, they could soften the cartilage at the bend, and then allow it to harden into its new shape – all without pain or scarring.

Next, the researchers are looking into other types of tissue, such as tendons and the cornea in the eye. The hope is that by painting electrodes onto a contact lens, it might be possible to temporarily soften the cornea and change its curvature, correcting vision problems.





THE LINK BETWEEN BOOZE AND KEBABS? IT'S ALL IN THE MIND...

A shared circuit in the brain could be the reason that doner kebabs taste amazing when you've been drinking, according to a new study from Pennsylvania State University.

The research team allowed a group of mice to gorge on high-fat foods for short periods, interspersed with a normal diet, while also having

free access to alcohol mixed with water. Over the course of the study, the group that feasted on high-fat foods consumed more alcohol than a group of mice who were fed a normal diet.

The researchers believe that these actions are linked because the consumption of high-fat foods and alcohol "may utilise the same neurocircuitry," according to Caitlin Coker, one of the authors of the study.

Trending

YOUR GUIDE TO WHO'S SAYING
WHAT ABOUT THE HOTTEST TOPICS
IN THE WORLD RIGHT NOW

#ParkerSolarProbe

On 4 April, NASA's Parker Solar Probe made its second close flyby of the Sun. The spacecraft launched in August 2018 with the mission of being the first probe ever to 'touch' the Sun, in an effort to understand more about its corona.

Nicky Fox

@SolarGirl2018

Fasten your seat belts – we're going in again!! @NASASun @JHUAPL #ParkerSolarProbe heads in for her second trip through the corona. #HelioRocks #obsessedwithspace

NASA Goddard

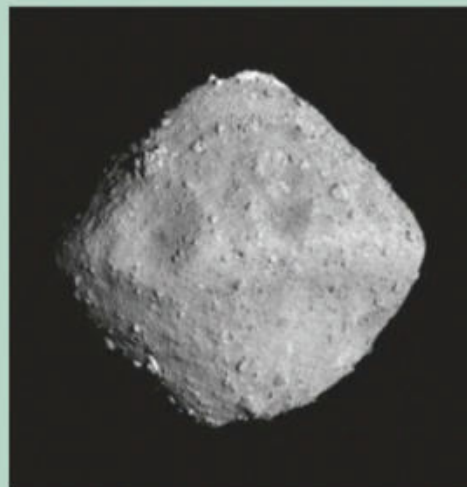
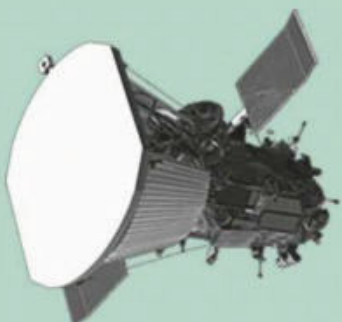
NASAGoddard

How time flies! Today, #ParkerSolarProbe is making its second close approach to the Sun. A little over a year ago, the spacecraft was undergoing some of its final testing here at Goddard

Jason Kalirai

@JasonKalirai

Exciting day for @NASA space science. #ParkerSolarProbe will achieve its 2nd perihelion in just a few hours. As it flies through the Solar corona at 213,200 miles/hour, it will collect unprecedented observations of our star.



#Hayabusa2

Japanese spacecraft Hayabusa2 successfully dropped an explosive device onto the surface of asteroid Ryugu, creating a small crater from which to gather samples when the eventually touches down on the asteroid's surface.

Roger Highfield

@RogerHighfield

Space probe #Hayabusa2 has pelted asteroid Ryugu with bouncing probes, shot a bullet at it, and taken a bite too. But now, the mission has performed its most daring manoeuvre yet: it dropped an explosive on the surface to create a small crater.

Hans Solo

@thandojo

#Japan's #Hayabusa2 spacecraft BOMBS #asteroid #Ryugu with a baseball-sized explosive to create a crater that it can use to collect underground samples The copper explosive is roughly the size of a baseball and weighs around 4.4lbs

#SydneyBrenner

Nobel prize-winning biologist Sydney Brenner passed away on 5 April. Despite being born into poverty and teaching himself to read from newspapers that were being used as tablecloths in his family home, Brenner became one of the leading figures in molecular biology at the University of Cambridge in the 1960s.

Dr Melvin Sanicas

@Vaccinologist

In 2007, I had occasional lunchtime chats with this witty, funny, brilliant man who seemed to know everything about #biology & the #lifesciences industry. I only found out months later that this man who patiently answered my noob questions was Prof #SydneyBrenner. #RIP Dr Brenner.

José-Eduardo Gomes

@JoseEdGomes

Brenner, Jacob and Meselson's 1961 paper on the discovery of mRNA is still one of my all-time favourite scientific papers, the logic and design are breathtakingly brilliant, this "strange" RNA was known for years and no one could figure out its function. #SydneyBrenner



#SaveTheBees

Bavaria has announced that it will pass into law a "save the bees" petition to alter farming practices that are potentially harmful to insect life, after it received 1.75 million signatures.

Friends Of The Earth

@friends_earth

If Bavaria, Germany can do it, so can we. They got 1.7 million signatures to #savethebees (and all pollinators) and now they have a change in the law to cut pesticide use and increase organic farming and flower meadows.

Matthieu H Arnoult

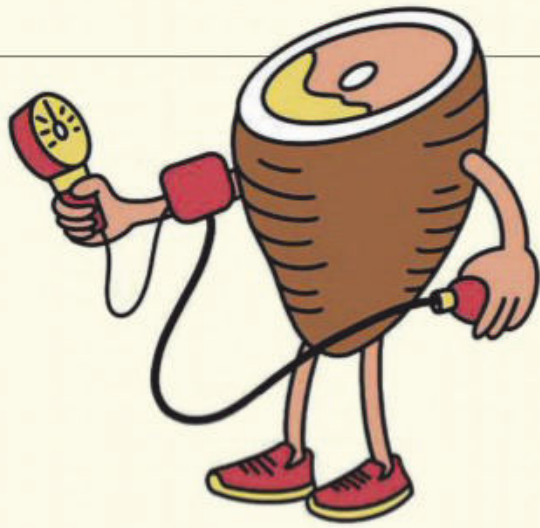
@Catalaunensis

From one #Petition to the next, from #Revoke to #SaveTheBees: "10% of green spaces in #Bavaria would have to be turned into flowering meadows, and rivers and streams better protected from #pesticides and #fertilisers" under the new law.

KEEP IN TOUCH



@SCIENCEFOCUS



IBERICO HAM MAY HELP TO LOWER BLOOD PRESSURE

This is good news however you slice it! Spanish researchers have found that 'heart-healthy' peptides – small, protein-like molecules – found in dry-cured ham could help to reduce blood pressure and protect against type 2 diabetes and obesity. Olé!

In numbers

1.5

megabytes

The amount of data native speakers need to retain to fully learn the English language, as calculated by a team at the University of California.

4,000

years

The age of a sample of bog butter – a Bronze Age dairy product that ended up submerged in peat, which preserved it – found in Knockdrin, County Westmeath, and dated by a team at the University of Bristol.

1 billion

The number of people who, due to rising temperatures attributed to climate change, will be newly exposed to viral diseases carried by mosquitoes such as dengue, chikungunya and Zika over the next 50 years, as estimated by the Georgetown University Medical Center.

HEALTH

House dust could be causing us to pile on the pounds

Household dust has been found to contain up to different 70 chemicals that may encourage the growth of human fat cells

If you're looking to lose a little weight this year, it could be time for a spring clean. Researchers at Duke University have found that house dust contains chemicals which could be causing us to pile on the pounds.

Endocrine-disrupting chemicals – compounds that replicate hormones naturally found in the body – in household dust may trigger the development of fat cells in humans, the researchers say. The effect could be triggering increased fat growth in children, relative to that expected for their age.

Previous research on fat cells isolated in the lab has shown that exposure to certain endocrine-disrupting chemicals can cause them to accumulate triglycerides – a type of fat found in the blood. For this latest study, the team collected nearly 200 house dust samples from homes in North Carolina. They then extracted more than 100 different chemicals from the dust in the lab and tested each of them for their ability to promote fat cell development in a petri dish model. They found that around 70 of the chemicals had a marked effect on the development of dust-induced fat cells. What's more, they also discovered that several of the chemicals were present in large quantities in the dust found in the homes of children who were significantly overweight or obese. The Environmental Protection Agency estimates that children consume around 60 to 100 milligrams of dust a day.

"This is some of the first research



Dusty houses can irritate asthma sufferers, but new research suggests they may be bad for the waistline, too

investigating links between exposure to chemical mixtures present in the indoor environment and the metabolic health of children living in those homes," said lead researcher Dr Christopher Kassotis. "We found that two-thirds of dust extracts were able to promote fat cell development, and half promote precursor fat cell proliferation at 100 micrograms, or approximately 1,000 times lower levels than what children consume on a daily basis."

The team plans to study these chemicals further, to establish exactly which (if any) of them should be considered a contributing factor to obesity in children.



ZOOLOGY

Look for the bear necessities



Sun bears are omnivores. They primarily feed on insects such as termites and ants, and fruit such as figs.

30%

Sun bears are listed as Vulnerable on the IUCN Red List. The global population has declined by more than 30 per cent over the past 30 years.



Sun bears can live up to 30 years in captivity.

Sun bears can precisely copy the facial expressions of other bears. This is the first time that this kind of mimicry-based communication has been seen in animals other than humans or gorillas.

The sun bear, also known as the honey bear due to its love of the sweet stuff, is the world's smallest bear species. It lives in the jungles of southeastern Asia and is usually solitary in the wild, which makes its newly discovered ability even more unexpected – skills such as being able to read facial expressions tend to only be found in highly social animals like primates.

“Mimicking the facial expressions of others in exact ways is one of the pillars of

human communication,” said Dr Marina Davila-Ross from the University of Portsmouth, who led the research. “Other primates and dogs are known to mimic each other, but only great apes and humans were previously known to show such complexity in their facial mimicry.”

Over the course of the two-year study, 22 bears played together hundreds of times, and their facial expressions were recorded. The scientists found that mimicry was seen most often during gentle play. According to Derry Taylor, who also took part in the research, the behaviour could help the bears to communicate that they want to play more roughly, or intensify social bonds.

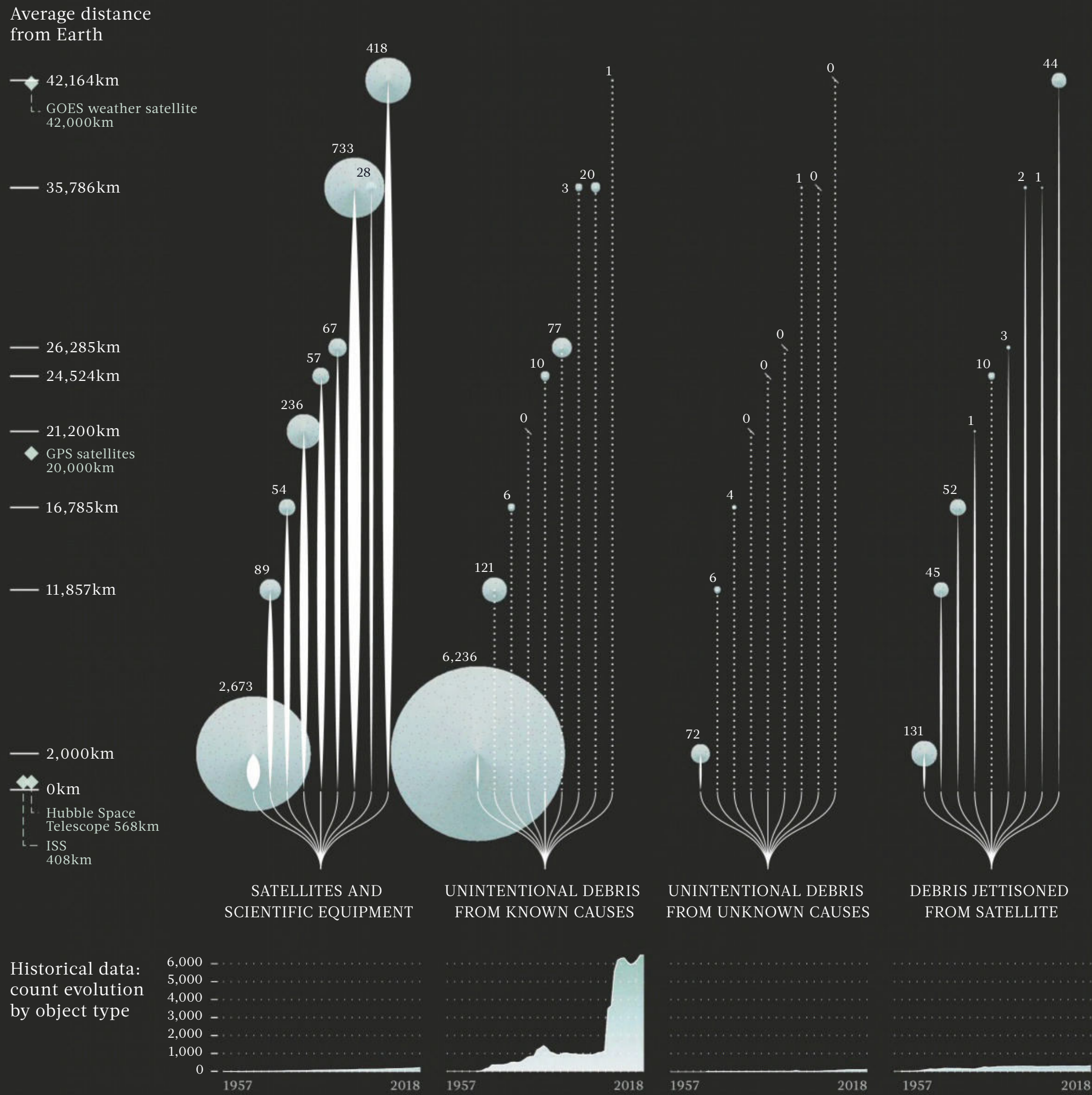
Sun bears live alone in the wild, yet have skills usually associated with social animals

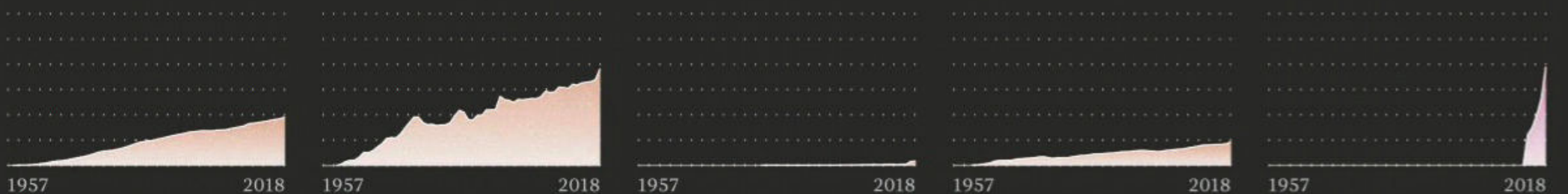
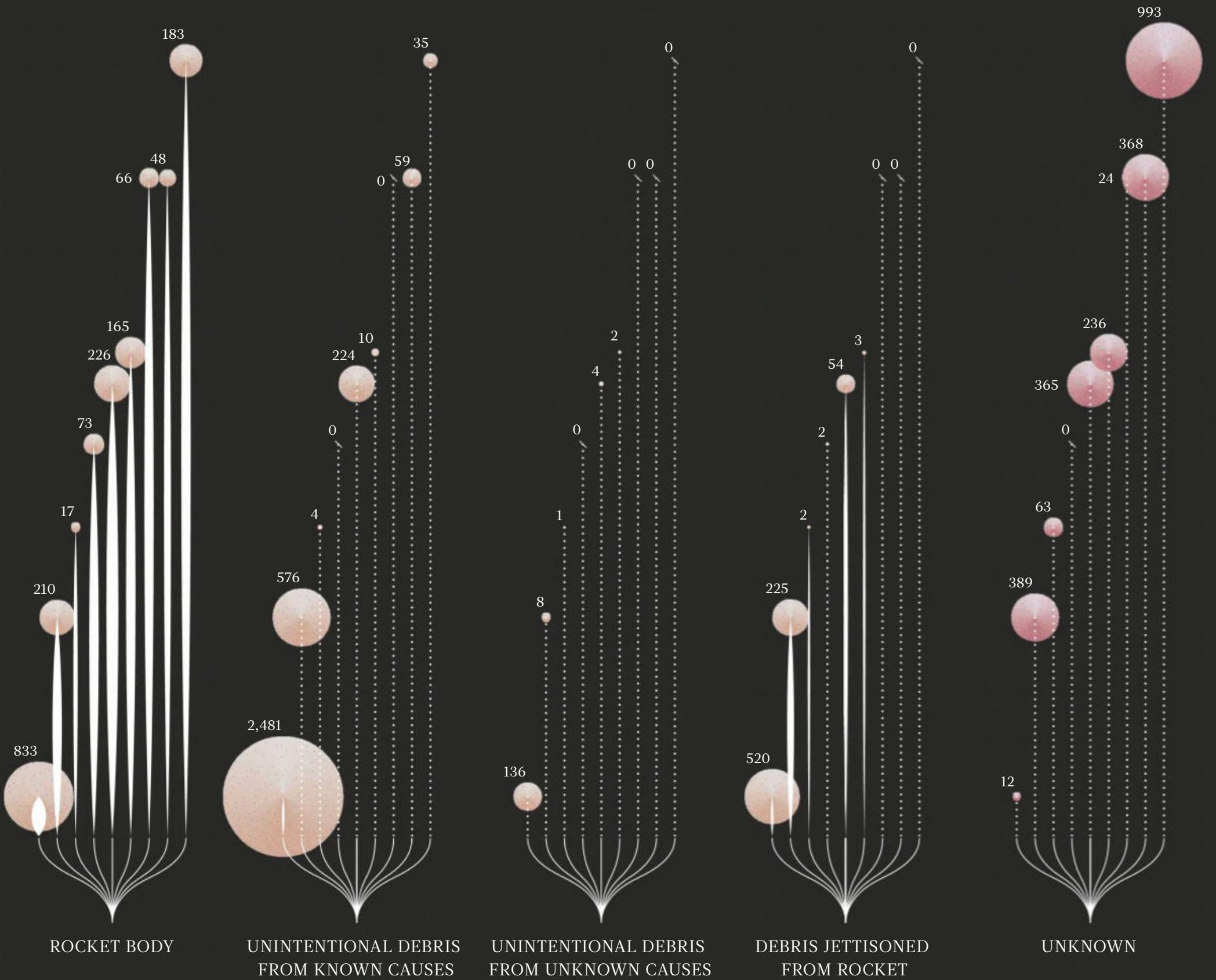
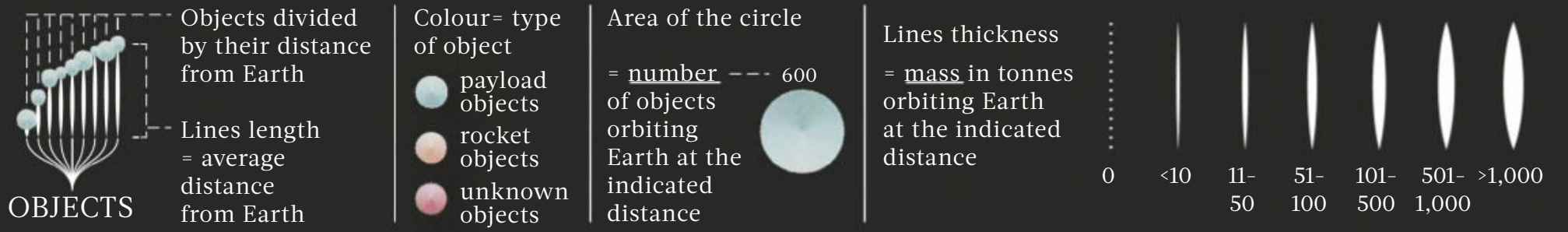
Data crunch

Space junk

India recently shot down a satellite using a missile launched from Earth. NASA raised concerns that the resulting debris could collide with other satellites or the ISS. As the destroyed satellite was in a low orbit of just 300km, the debris will burn up as it falls back to Earth over the coming weeks. However, space junk has been increasing over the last few decades and collisions could increase if the problem is not kept in check.

INFOGRAPHIC: FEDERICA FRAGAPANE







WATCH YOUR STEP

Careful where you walk this spring; queen bumblebees might be sleeping underfoot, gaining strength before moving to their next nest. Scientists at Queen Mary University in London have discovered that after emerging from hibernation, queens spend the majority of their time resting

on the ground, only occasionally flying for 10 to 20 seconds in any direction. "A few weeks of this type of behaviour would carry queen bees several kilometres away from their hibernation site," said study co-lead Dr Joe Woodgate. It could explain how queens disperse from their birth nests to found new colonies.

MEDICINE

What's up, dog?

Pooches can sniff out lung cancer with nearly 97 per cent accuracy

We all know that dogs are great for companionship and encouraging us to get off the settee to go for a walk, but here's yet another reason to love them. According to recent research, man's best friend is capable of sniffing out cancer in blood samples.

For the study, which was carried out by Florida-based research company BioScent Dx, four beagles were taught to use their sense of smell to distinguish between the blood of healthy people and the blood of patients with malignant lung cancer. After training, three of the dogs successfully identified lung cancer samples 96.7 per cent of the time, and normal samples 97.5 per

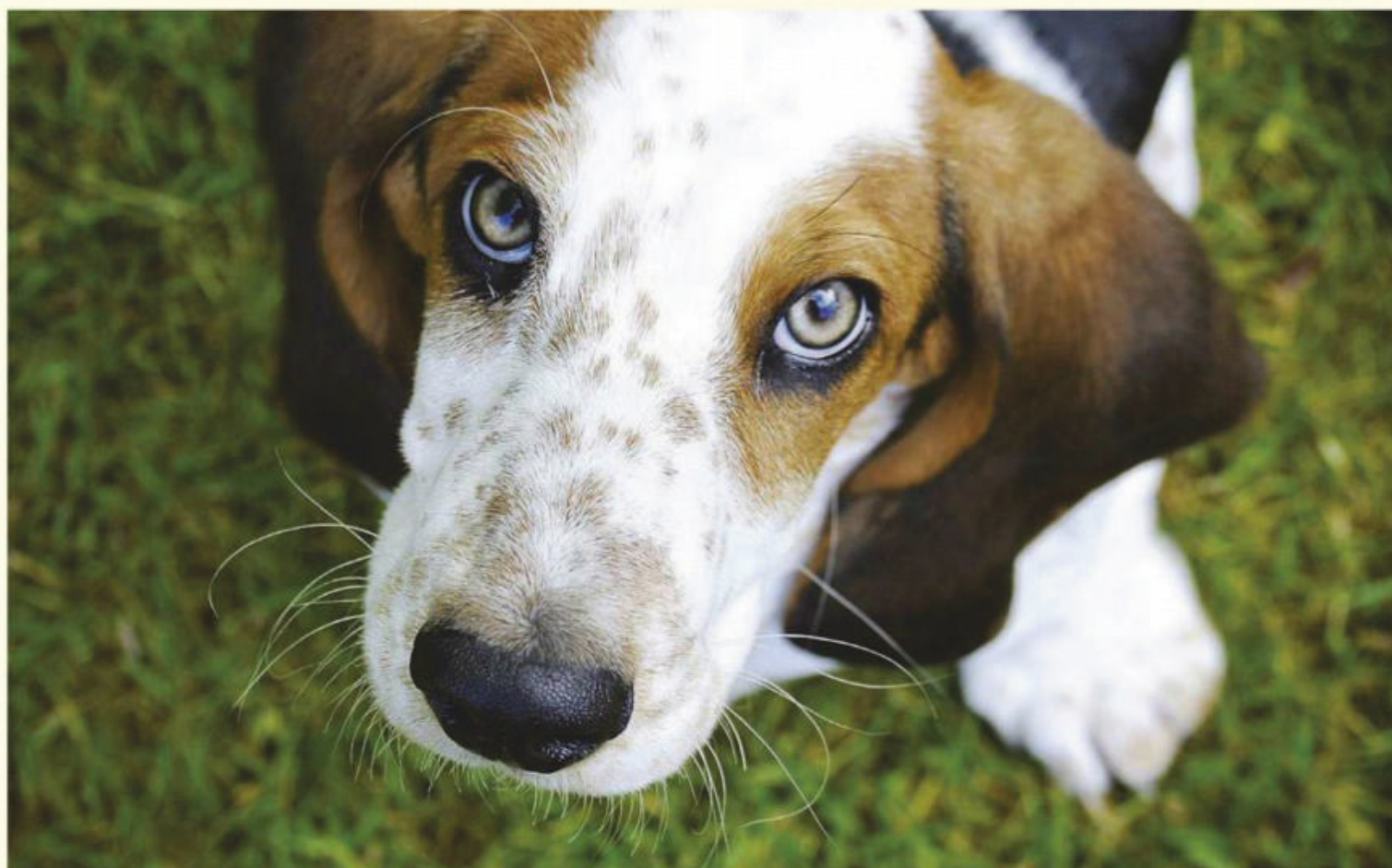
cent of the time. The fourth dog, Snuggles, did not have any interest in performing.

"This work is very exciting because it paves the way for further research along two paths, both of which could lead to new cancer-detection tools," said Heather Junqueira, who led the research. "One is using canine scent detection as a screening method for cancers, and the other would be to determine the biologic compounds the dogs detect and then design cancer-screening tests based on those compounds."

Early detection of cancer offers patients the best hope for survival, and sensitive, cost-effective tests could help save many

lives. BioScentDx wants to use dogs to create non-invasive ways of screening for cancer and other diseases. Late last year, the company launched a study in which breast cancer patients submitted samples of their breath for screening by the detection dogs.

Dogs' smell receptors are around 10,000 times more accurate than ours, which means they can detect scents that are simply imperceptible to us. Of all the dog breeds, beagles have some of the best noses, which means they're pawsitively (sorry) brilliant at sniffing out diseases, as well as prohibited substances and explosives.



Dogs can smell in stereo – each of their nostrils can take in scents independently, giving them a sense of what direction a certain smell is coming from.



Dogs have a 'nose print' pattern of ridges on their noses that are thought to be as unique to them as a human fingerprint is to us.

300 million

The number of scent receptors in the nose of a bloodhound, which is the breed of dog with the keenest sense of smell. Humans have just five million.

Primer

Synthetic alcohol

COULD ALCARELLE, A SYNTHETIC ALCOHOL SUBSTITUTE BEING DEVELOPED IN UK LABS, SPELL THE END OF BINGE DRINKING, HANGOVERS, AND ALCOHOL-RELATED DISEASES?

WHAT EXACTLY IS IT?

Originally known as Alcosynth, Alcarelle is the latest name for a synthetic alcohol substitute being developed by Prof David Nutt. The goal is to produce a safe and responsible alternative to alcohol that can provide the beneficial relaxing and social-lubricating effects without the downsides of getting too tipsy, suffering from hangovers, or causing damage to the liver or other organs. Its exact chemical composition, however, remains a closely guarded secret.

WHO IS DAVID NUTT?

Prof Nutt is the director of the neuropsychopharmacology unit at Imperial College London. He was formerly the chair of the UK's advisory committee on the misuse of drugs before being dismissed in 2009 for his comment that horse riding was more dangerous than the recreational drug ecstasy. He has since carried out pioneering work on the potential uses of psilocybin, which is the psychoactive chemical found in magic mushrooms, in helping with the treatment of depression.

HOW DOES IT WORK?

Nutt is playing his cards close to his chest, but he has stated that the original idea came to him when he was studying the effects of alcohol on GABA



×

The goal is to produce an alternative to alcohol that can provide the relaxing and social-lubricating effects without the downsides

receptors in the brain. GABA, or gamma-aminobutyric acid, is a neurotransmitter that blocks signals fired between different nerve cells in the brain. It is widely associated with triggering feelings of sedation and relaxation. When we drink alcohol it binds onto GABA receptors and mimics the effect of the GABA neurotransmitter. This is why

we feel relaxed or sleepy after drinking. However, if we consume too much alcohol the GABA pathways can be overstimulated leading to an extreme sedation of the central nervous system. In the case of Alcarelle, Nutt and his team aim to create a molecule that binds to GABA receptors in a specific way to induce the relaxing and social-lubricating effects of alcohol, without any of the downsides.

HOW SAFE IS IT?

As it stands, only a few of the researchers at the lab have tried Alcarelle, so the jury is still out. Nutt estimates that it would be around 100 times safer than traditional alcohol. A drinker would only need to consume a few micrograms of Alcarelle to get the same effect as a regular drink, which typically contains a few grams of alcohol. The team plans to work with food scientists to rigorously test Alcarelle's safety, with the end goal of having it regulated as a safe-to-consume ingredient within the next five years.

COULD IT BECOME ADDICTIVE?

Again, we can't say for sure without knowing its full chemical make-up. Nutt and his team say that as they know chemically what causes some of us to become addicted to alcohol and other drugs, they can make sure that this effect is not present in Alcarelle.

HOW WILL IT BE USED?

Apparently, Alcarelle doesn't taste particularly pleasant by itself. In the lab, it has been mixed with fruit juice. If it does ever make it to market, it therefore seems most likely that it will be as a complete pre-mixed drink, which would then be sold in bottles or cans – just like any other beverage that has been deemed as fit for consumption under standard UK food safety and hygiene regulations.



Thomas McDade Human biologist

Horizons

Growing up poor can affect your DNA as well as your health

PREVIOUS RESEARCH HAS SHOWN THAT A LOW SOCIOECONOMIC STATUS LEAVES PEOPLE MORE LIKELY TO SUFFER FROM INCREASED RISK OF HEART DISEASE, DIABETES, CANCER AND INFECTIONS. BUT NOW, SCIENTISTS HAVE FOUND THAT THIS MAY BE BECAUSE BEING POOR AFFECTS GENES AT THE DNA LEVEL

WHAT DID YOU FIND IN THE STUDY?

We've known for a long time that individuals who have a lower level of socioeconomic status suffer from worse health throughout their lives. They die earlier, they are at increased risk of cardiovascular diseases, metabolic

diseases, infectious diseases – basically everything on the social gradient of health. But it's been a bit of a mystery how that happens. How is it that our bodies in a sense remember the experiences that we have had growing up? And how do those experiences – in this case experiences associated with socioeconomic status – affect cellular function and physiology with implications for health? We found that lower levels of socioeconomic status were associated with DNA methylation on a large number of sites across a large number of genes – more than 1,500. To me, this was somewhat surprising. We are showing that socioeconomic status touches nearly 10 per cent of the genes in our bodies and has the potential to affect their structure and function.

We are finding that DNA methylation might provide this mechanism for memory, for translating the experiences with respect to socioeconomic environments into biology and then possibly downstream to health.

SO WHAT EXACTLY IS DNA METHYLATION?

All of our cells contain DNA, which is a series of sequences of bases known as A, G, T and C. DNA methylation is a biochemical process where methyl groups are added to particular sites in the DNA sequence called 'CPG sites'. In the genome, there are areas where there are clusters of these CPG sites. The methyl groups get added to these sites and they affect the likelihood that a gene will be expressed. That's what really matters. You can inherit a gene from your parents that might have some adverse consequences on your health, but if that gene is not expressed it doesn't matter.

WHERE DOES THIS FIT INTO THE WHOLE NATURE VERSUS



Social inequality is a problem all around the world, and may actually be affecting people's DNA



“The genome is a dynamic substrate that literally changes its structure and function in relation to experience”

GETTY IMAGES



NURTURE ARGUMENT?

We tend to think of genes as something that is fixed that defines our destiny. We inherit them from our parents, and therefore at conception our fate is sealed. That's a relatively simplistic model of genetic determinism, which is surprisingly common.

But this idea is not up to date with contemporary genomics and how we know genes matter to health. The term 'epigenetics' literally means 'on top of the genome'. It's the broader class of modifications to the structure of genes that affect their function. One of the fascinating opportunities in this line of research, especially when we talk about epigenetics, is to think about the genome as part of our biology that needs input from the environment to shape its development and function. It challenges us to think about genes a little bit

differently, to think about the genome as a dynamic substance that literally changes its structure and function in relation to experience.

Experiences that you have as you grow up shape the biochemistry of your genes in altering their structure and function. So to me, the whole nature and nurture thing totally breaks down. Genes cannot function in a vacuum. Similarly, environments can't have effects on our bodies and health independently of their impact on the genome without shaping patterns of gene expression. There is no nature versus nurture. It's nature through nurture – nature and nurture working together in conversation through the course of development.

DID YOU MANAGE TO PINPOINT ANY SPECIFIC EFFECTS?

We can't answer that with this study

but that is where we are going next. We are following these participants so we will be able to see what patterns of methylation at one point in time during young adulthood predict health problems later in life. We have a lot of data from multiple points in time where we can look at where individuals accessed healthcare, how much food they ate, what kind of food they ate, how frequently they were sick. That's where we are going to go next.

PROF THOMAS MCDADE

Thomas is a director of the Laboratory for Human Biology Research at Northwestern University. Interviewed by BBC Science Focus commissioning editor Jason Goodyer.



SPACE

NASA'S MARTIAN HABITAT CONTEST ENTERS FINAL STAGE

With the 'virtual construction' stage complete, competing teams are now set to face each other in a final 'build-off'



The winners of the penultimate stage of NASA's 3D-Printed Habitat Challenge – a competition launched in 2015 to create sustainable shelters suitable for use by settlers on the Moon, Mars or beyond using resources available on-site – have been announced. In this 'software modelling' stage, each of the 11 teams was awarded points based on the architectural layout, efficient use of interior space and constructability of their design, with SEArch+/Apis Cor, Zopherus and Mars Incubator bagging the top three spots and sharing \$100,000 (£76,600) in prizes. The teams will now compete for a prize purse of \$800,000 (£613,150) in a head-to-head print-off to create scale models of their designs at the final in Peoria, Illinois on 1-4 May.

TEAM SEARCH+/APIS COR, TEAM ZOPHERUS, AI SPACEFACTORY



1. This rather striking beehive-like structure was the design submitted by the team from AI SpaceFactory, an architectural practice based in New York. The design (named 'MARSHA') missed out on a prize this time around.

2. SEArch+/Apis Cor's chimney-like design took first place in the software

modelling round. The unique shape of their habitat allows it to be continually reinforced, and lets light in through trough-shaped ports on the building's sides and top.

3. Second prize in the software modelling stage went to Team Zopherus from Rogers, Arkansas. Their design would be

constructed by an autonomous roving printer; once it has completed one structure, it can move on to the next site.

4. After they've been 3D-printed, Zopherus's buildings can be insulated with materials gathered on-site from the Martian regolith.

5. This modular structure made up

of interlocking polyhedral pods was the brainchild of Mars Incubator. Based in New Haven, CT, the team were awarded third place in the software modelling round for their efforts. Along with the other two prize-winning teams, they will now build the structure for real in the competition final in May.



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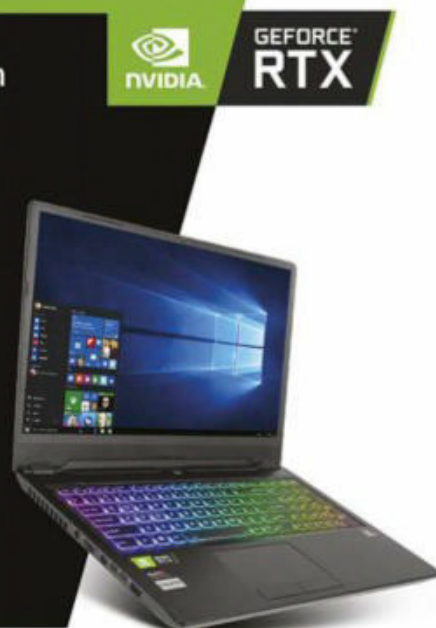
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**1** REVIEW**HEAVY METAL: IS
IT BAD FOR YOUR
MENTAL HEALTH?**

Heavy metal music has long been blamed for violence and hostility, but it turns out that fans could feel happier for listening...

Historically, heavy metal music, arguably more than any other genre, has a reputation for the effect it has on its listeners' behaviour and mental health. Studies have suggested a link between listening to heavy metal and increased suicide risk or desensitisation to violence, but these have often failed to take account of outside factors, such as poor family relationships, drug abuse and feelings of alienation. Even though a recent 2018 study at Macquarie University in New South Wales found that music with violent themes does not make fans more aggressive, it might take some time for heavy metal's image to change.

In 1996, the band Slayer were sued by the parents of a 15-year-old who had been murdered by three of their teenage fans. The parents accused Slayer of being responsible for her death, but the case was later dropped.

WANT MORE?



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Kerry King
of Slayer
performing
on stage



“The researchers found that the extreme music improved their emotional state, and could help with processing”

Judas Priest and Ozzy Osbourne both faced lawsuits after incidents of their fans committing suicide after listening to their music.

It doesn't desensitise you to violence

However ignoble the passions that heavy metal music ignites, the effect it has on its fans isn't as negative as you might expect. According to the researchers at the aforementioned Macquarie University study, regular listeners, although much more blasé about the contents of the lyrics, responded equally to violent imagery as non-listeners.

Fans' sensitivity to violence was tested using a standard technique known as 'binocular rivalry'. Test subjects are shown two different images at the same time, one to each eye. The brain, which is used to combining two similar images to produce one three-dimensional image, chooses one to perceive while the other is suppressed.

One of the images presented is violent in nature, while the other is neutral. Ordinarily, the brain prioritises the violent image, which helps it to identify and assess threats. The researchers asked

both fans and non-fans to indicate when they perceived each image, and found that both groups showed the same bias for processing the violent image first.

It can make you happier

In fact, for fans of the genre, the music could be helpful, providing emotional release. In 2015, a study at the University of Queensland asked for participants who were fans of extreme music. They made them angry, then allowed them to listen to the music of their own choice and assessed how their emotional state had changed. The researchers found that the extreme music improved their emotional state, and could help with processing anger.

In the study at Macquarie University, fans of death metal reported using the music's emotional charge to motivate them or to work through feelings of anger. This effect appears to extend to vulnerable listeners, and in particular adolescents. A 2001 study in the *Journal Of Youth And Adolescence* found that, when outside factors were taken into account, heavy metal did not influence suicide risk among adolescents. Further to this, teenage girls who used the music

as an emotional release were actually at lesser risk.

It can help you become part of a community

One common feature of many of these studies is that the uninitiated find listening to heavy metal music to be an extremely unpleasant experience. However, for fans, the opposite is true.

Anthropology PhD student Lindsay Bishop studied the heavy metal community around the world and found a strong sense of community, inclusivity, and even well-defined mosh pit etiquette. While many listeners might find the music distasteful, its fans are usually perfectly pleasant.

by SARA RIGBY

Sara is the online assistant for BBC Science Focus. She has an MPhys in mathematical physics.

DISCOVER MORE



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2

ANALYSIS

TRANS ATHLETES: CAN THEY BE FAIRLY INTEGRATED INTO WOMEN'S SPORTS?

Recently, high-profile athletes like Kelly Holmes and Paula Radcliffe hit the headlines after calling for more research into the performance of trans athletes. Do they have a point?



Ever since 2003, the International Olympic Committee has allowed transgender athletes to compete in the Olympics under the gender with which they identify. According to their 2015 guidelines, transgender women don't need legal recognition of their gender, but must limit their testosterone levels. Some elite athletes, including

Paula Radcliffe and Dame Kelly Holmes, have recently criticised this, calling for more research into whether transgender women have inherent athletic advantages over their cisgender (someone whose gender aligns with their biological sex) competitors. This idea stems from the fact that men are, on average, taller than women, with higher testosterone levels and greater

Many elite athletes are calling for more research into the sporting performance of trans women

muscle mass. On top of this, men tend to have less fat mass, greater bone density and a higher capacity to carry oxygen in the blood.

In total, an elite male athlete performs, on average, 10 per cent better than a female equivalent. Some athletes believe, therefore, that transgender women retain an advantage after transitioning. However, there is not yet enough

evidence to draw a conclusion either way.

Take, for example, muscle mass. During a male-to-female transition, the hormone testosterone is suppressed. Testosterone plays a role in building muscle, so suppressing it causes muscle mass to die away. However, it might be possible that the muscle retains its capacity to grow to its former size.

“The muscle atrophies – there’s no doubt about that,” says Yannis Pitsiladis, professor of sport and exercise science at the University of Brighton. “But does the muscle still have the potential to grow like a male muscle, given that it’s been in that environment for a long time?”

The capacity for growth in a muscle lies in the contents of its cells. They are unusual in that each one can contain multiple nuclei, known as myonuclei, and the number of myonuclei determines how big the muscle can grow. “It’s the myonuclei that permit the laying down of more muscle fibres and therefore bigger muscle cells,” says Pitsiladis. “If one goes to the gym and exercises, the myonuclear number goes up.”

A high testosterone level also results in a high myonuclear number. “It appears that once it goes up, that number stays up: it doesn’t go down,” Pitsiladis says. As a result, muscles appear to have a long-term ‘muscle memory’ of their capacity to grow, even after testosterone is lowered. But Pitsiladis is keen to point out that this muscle memory effect has so far only been observed in mice.

MORE THAN MUSCLE

What’s more, muscle on its own is far from a deciding factor. While a transgender woman might have a larger skeleton than a cisgender woman, that’s not necessarily a benefit. “From a biomechanical point of view, there may be advantages, but there could also be disadvantages,” says Pitsiladis.

For example, oxygen-carrying capacity decreases over the

transition with the decreasing levels of haemoglobin. “You have a bigger body, and you have a smaller engine to move that vehicle around,” he says. A bigger frame may be helpful for basketball players or long-jumpers, but it could equally prove cumbersome for gymnasts or jockeys.

Studying these individual factors on their own is not enough to determine the fairness of competition between transgender and cisgender women. More than muscle mass or haemoglobin levels, research needs to be directed at changes

study were not athletes, and none of the physical changes studied directly measured athleticism.

FAIR GAME

The only study to date which has measured the changing athleticism in transgender athletes was performed by medical physicist, long-distance runner and transgender woman Joanna Harper. She compared the race times of herself and seven other transgender female distance runners before and after transition, using a comparative method called ‘age grading’, which

×

“In a civilised, modern society, we should be able to deal with these matters in a non-emotive way”

—

in athletic performance over the course of transition. “Until we do those kinds of studies in humans who are transitioning, it’s really all conjecture,” Pitsiladis says.

In 2016, a review of the research into transgender athletes found no papers that provided evidence of transgender women having any athletic advantage over cisgender women. Whether this is because there actually is no advantage, or because of the lack of research in the area, is however unclear. “There is very little science there,” Pitsiladis says. “We are desperately trying to get our studies underway.”

One key study was carried out in 2004 by Louis Gooren and Mathijs Bunck of VU University Medical Center Amsterdam, and looked at physical changes over the course of transition. They found significant overlap in muscle mass between transgender and cisgender women, and concluded that the two groups could reasonably compete. However, the participants in the

assesses a runner’s performance by assigning a score relative to the best race time from a runner of the same age and gender.

Harper’s study found that the runners all performed to a similar level, relative to the appropriate competitors, before and after transition. It’s worth noting that the small group of participants in this study were not elite athletes, and that conclusions about other sports cannot be drawn from this one.

Pitsiladis believes research into the performance of transgender athletes is well worth doing. “We need to do those kinds of studies and look at how best to integrate in a way that is also fair on cisgender athletes,” he argues. “In a civilised, modern society, we should be able to deal with these matters in a non-emotive way. We should get rid of emotion and just deal with the facts.”

—
by **SARA RIGBY**

Sara is the online assistant for BBC Science Focus. She has an MPhys in mathematical physics.

3 COMMENT

BLUE PLANET II: DID IT HAVE AN IMPACT ON PLASTIC POLLUTION?

Marine plastic pollution burst into the public consciousness when *Blue Planet II* aired. Eighteen months on from the series, have we made any headway?

B *Blue Planet* is an amazing series, making the diversity of life in our seas and oceans accessible to all. As well as enjoying the series and using clips in my teaching, as a scientist I've been delighted to contribute ideas and help with fact checks.

Blue Planet II took a critical step by also highlighting the challenges affecting our oceans. There were concerns that this might be less appealing to wider audiences, but these were unfounded: YouGov rates it as the fourth most popular TV programme of all time in the UK.

One such issue is that of plastic pollution, something I have researched for over 20 years. Publication metrics tell me I have

In the UK, TV images of plastic pollution in our oceans have inspired the general public to act, but is it enough?



written more scientific papers on the topic than anyone else – but science alone is of limited value unless communicated. That's especially important with plastic pollution where actions by all of us, in daily life, are needed to make a difference.

There has been a marked increase in interest in plastic pollution; some in the field call this “the *Blue Planet II* effect”. Michael Gove, for example, was apparently haunted by the images of plastic bags in one episode. Images of seabirds regurgitating plastic debris, much of it household waste, were particularly harrowing.

A few minutes of coverage by *Blue Planet II* has done more to raise awareness than the decades of underlying research could ever have done alone. But perhaps the most important *Blue Planet* effect has been in bringing the message not just into the living room, but into the boardroom. This is crucial, because many of the issues relating to the fate of end-of-life plastics stem from a lack of consideration at the design stage. It's up to companies to design plastic products for circular use, and to recognise that the waste management infrastructure a country can put in place depends on its level of economic development.

A step change in awareness is one thing, but what's actually changed since the series went on air in October 2017? In 2018, twice as many volunteers participated in the Great British Beach Clean than the year before, and they reported on average a 16 per cent decrease in the number of items collected. But on a global scale, the problem has more than likely worsened. The quantities of plastic used and waste generated are both increasing, and the amount of plastics in the oceans is predicted to triple between 2015 and 2025.

Levels of interest in the UK have translated into positive action to remove litter from shorelines. This is a fantastic achievement, but clean-up on its own will not fix the problem. More systemic change is required, and that will take time. Over the last 60 years, we have become accustomed – some would say addicted – to the convenience of single-use plastics. It has become acceptable for items to be used in an instant, even though the resultant waste persists for decades.



“Levels of interest in the UK have translated into positive action to remove litter from shorelines. This is a fantastic achievement, but clean-up on its own will not fix the problem”

The past 18 months have also brought longer-term initiatives. Members of WRAP's UK Plastic Pact have committed to making 100 per cent of plastic packaging reusable, recyclable or compostable by 2025. Companies from manufacturers to retailers have signed up, as have the Scottish and Welsh governments and the Department for Environment, Food and Rural Affairs. The government's 25-year Environment Plan sets a target of zero avoidable plastic waste by 2042.

In my view, the challenge going forward lies in matching potential solutions to the specific uses of plastic. How and where should we adopt the different strategies – reduce, reuse, recycle, biodegrade, compost? Evidence about the problem is now clear, but evidence about which specific actions to take, and in which circumstances, is far less clear.

If we are to effectively harness the *Blue Planet II* effect, we need greater clarity of evidence and communication to guide our direction toward appropriate solutions. Clearly, engaging the public about the problem of plastic pollution is doable, but transferring that interest to product design and waste management practices could well prove much more difficult.

by **PROF RICHARD THOMPSON**

Prof Richard Thompson discovered the presence of microplastics in the ocean. He has an OBE for services to marine science.

FOLLOW THE CONVERSATION



@mcsuk

The Marine Conservation Society is a UK charity that has been campaigning to protect aquatic life and prevent ocean pollution since 1983.



@sascampaigns

Set up by a group of Cornish surfers in 1990 to champion water quality, Surfers Against Sewage now campaigns against marine pollution generally.



@Imogennapper

Imogen Napper is a PhD candidate at the University of Plymouth, where she studies marine plastic pollution.



@SciMatty

Based at the Plymouth Marine Laboratory, Dr Matthew Cole studies the effects of human activity on marine environments.

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WATCHING THE DETECTORS

WHETHER DEEP UNDERGROUND
OR PERCHED ON A VOLCANO,
PARTICLE DETECTORS HELP
SCIENTISTS TO UNRAVEL THE
MYSTERIES OF THE COSMOS

Words: BRIAN CLEGG

STRIKING GOLD

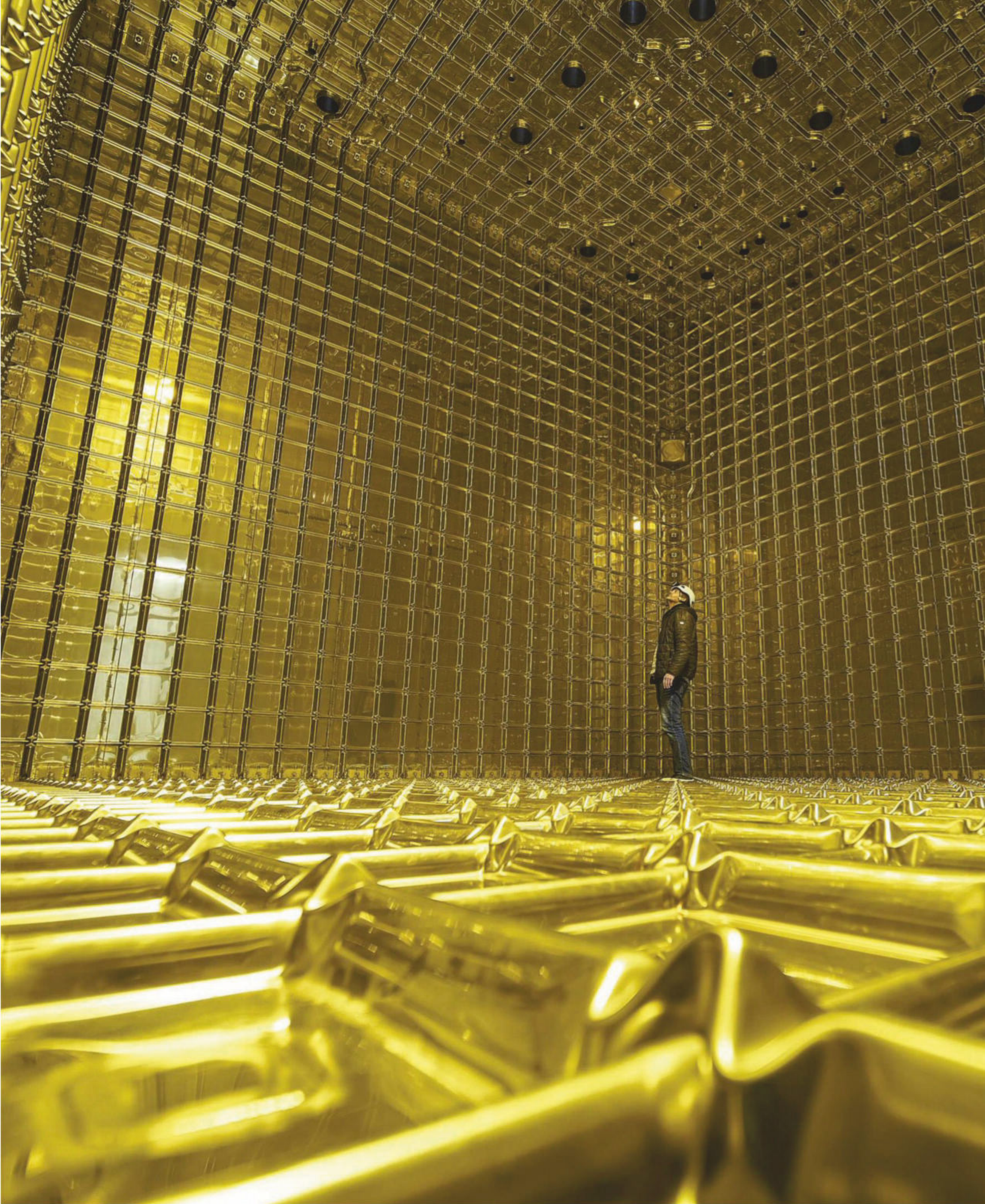
→ **PROTODUNE, FRENCH-SWISS BORDER**

DETECTING: **NEUTRINOS**

Bathed in yellow light to avoid overstimulating its sensors, this neutrino detector is the size of a three-storey house. Neutrinos are abundant – trillions pass through you every second – but they hardly interact with matter, making them tough to detect. When in operation, ProtoDUNE is filled with 800 tonnes of liquid argon. Sometimes, a neutrino makes a direct hit on an argon nucleus, producing a trail of charged particles detected by grids of wires around the detector. This prototype is being tested at CERN's headquarters, but DUNE (Deep Underground Neutrino Experiment) will be sited 1.5km underground in the disused Homestake gold mine in Lead, South Dakota. With four detectors, DUNE will pick up neutrinos generated by a particle accelerator 1,300km away at Fermilab, near Chicago. Expected to go live in 2026, DUNE will detect differences in behaviour between neutrinos and their antimatter counterpart, antineutrinos, which could help explain why the Universe has more matter than antimatter.

MAXIMILIEN BRICE/CERN





TANKS A LOT

↓ **HAWC (HIGH-ALTITUDE WATER
CHERENKOV OBSERVATORY), MEXICO**

DETECTING: **GAMMA RAYS**

In the shadow of Mexico's Pico de Orizaba volcano, these 300 steel tanks make up the HAWC, which is on the lookout for gamma rays – high-energy radiation that's created by cataclysmic events in space. When gamma rays hit our atmosphere, they produce a shower of fast-moving particles, which can interact with water molecules to create 'Cherenkov radiation', visible as an eerie glow. Each of the seven-metre-wide tanks is filled with water, plus detectors for picking up the radiation. By comparing the times at which particles arrive in the tanks, it's possible to work out the direction of the gamma rays. HAWC has recently been used to study the SS 433 microquasar, around 15,000 light-years away. SS 433 consists of a black hole consuming a star, pushing out jets of matter that generate gamma rays.

CATCHING WAVES

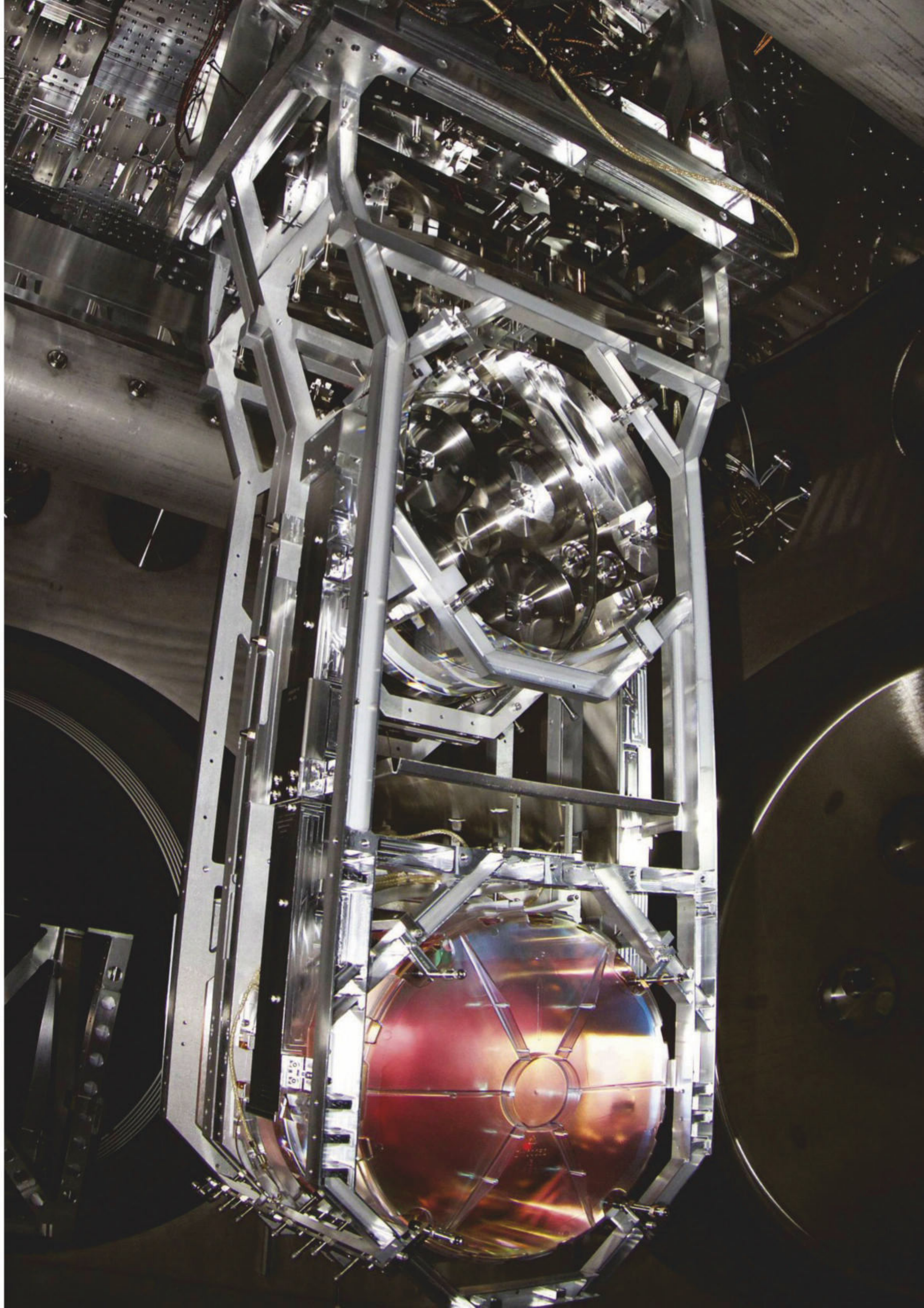
→ **LIGO (LASER INTERFEROMETER
GRAVITATIONAL-WAVE OBSERVATORY), USA**

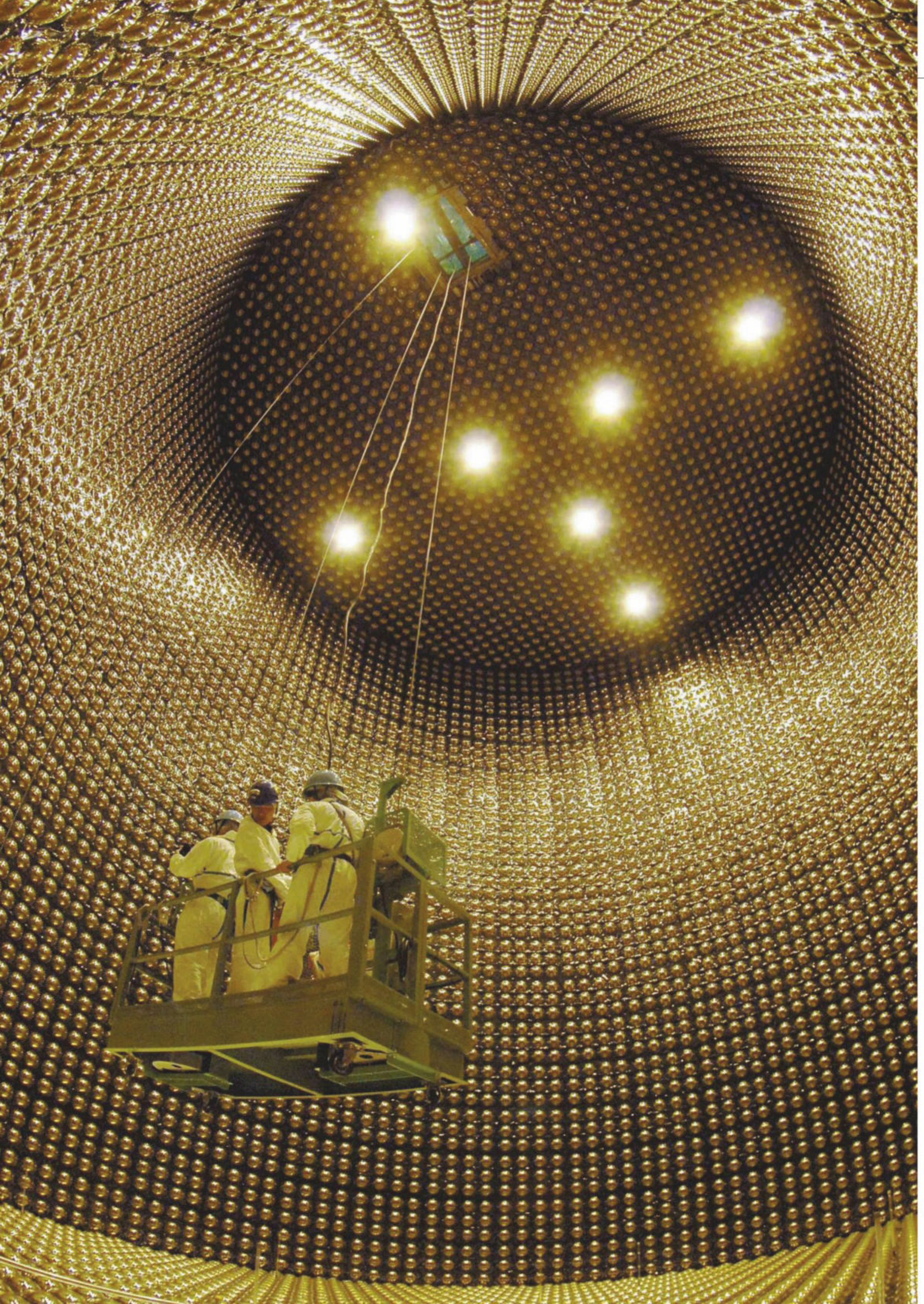
DETECTING: **GRAVITATIONAL WAVES**

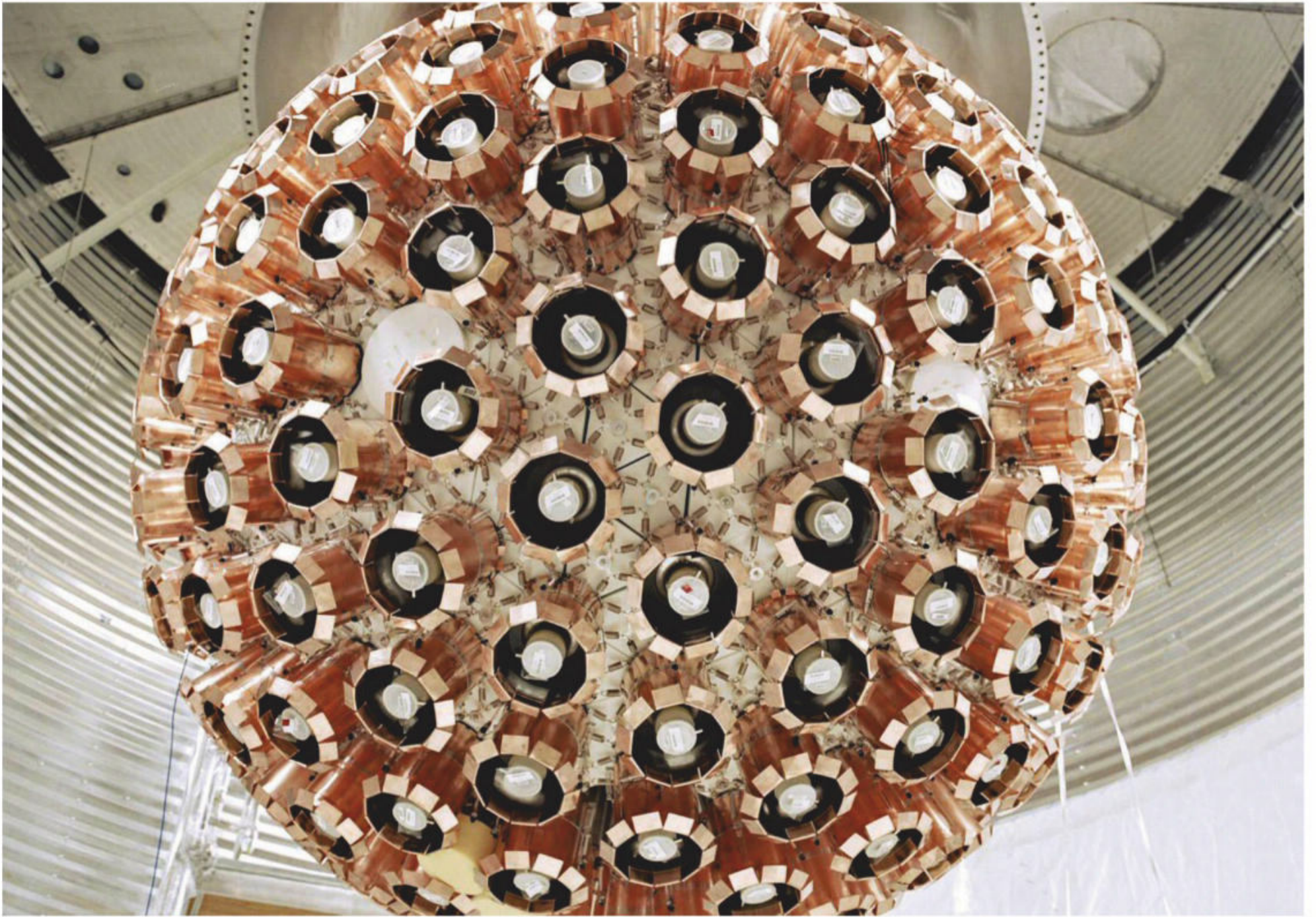
This 40kg, red-tinted mirror is suspended by an elaborate system designed to protect it from vibrations. This means that it's capable of detecting movements less than the size of an atomic nucleus, indicating the arrival of gravitational waves. Comprising two sites over 3,000km apart, LIGO is the first successful gravitational wave detector. Each LIGO site has a pair of four-kilometre-long tubes, which lasers repeatedly travel through, revealing movements in these mirrors. On 14 September 2015, astronomy was changed forever by LIGO's first detection of gravitational waves. Predicted by Einstein in 1916, these vibrations in the fabric of space-time are caused by cosmic collisions like merging black holes. So far, LIGO has detected 11 black hole and neutron star mergers, and is just starting a third run.



HAWC OBSERVATORY, NSF/MIT/CALTECH







LIGHT SHOW

← **SUPER-KAMIOKANDE, JAPAN**

DETECTING: **NEUTRINOS**

Over 13,000 light-detecting tubes line the Super-Kamiokande neutrino detector, one kilometre beneath Mount Ikeno in Japan. This is the granddaddy of such detectors, beginning operations in 1996. The 40m-wide tank holds 50,000 tonnes of pure water. When neutrinos collide with the water molecules, they produce fast-moving electrons, which generate Cherenkov radiation, detected by the tubes in this photo. Super-Kamiokande has been central to our understanding of neutrinos' weird behaviour. We know that the Sun produces vast quantities of neutrinos, but only about a third of them were being detected. Super-Kamiokande, along with Canada's Sudbury Neutrino Observatory, was used to show that neutrinos go through a process called oscillation, shifting between three different types in flight – which explained why so many were going undetected. This showed that – contrary to expectations at the time – neutrinos have mass, flagging up a gap in our understanding of how the Universe works.

GETTY IMAGES, SNOLAB

DEEP, DARK SECRET

↑ **DEAP-3600 (DARK MATTER EXPERIMENT USING ARGON PULSE-SHAPE), CANADA**

DETECTING: **DARK MATTER**

This flower-like array of photomultiplier tubes in the DEAP-3600 detector surrounds a chamber of liquid argon. The tubes are pointed inwards, looking for tiny flashes of light as incoming dark matter particles interact with the argon nuclei. If neutrino detectors have a tough job, at least we know what we're looking for. Dark matter, on the other hand, has proved trickier to pin down. This exotic matter – predicted by measurements that galaxies seem to have much more matter in them than is observed – should outnumber ordinary matter particles by around five to one. One theory is that dark matter is made of WIMPs ('weakly interacting massive particles'), and these are what DEAP-3600 is designed to look for. To reduce interference from other particles, the detector is located two kilometres underground in an old nickel mine at Sudbury, Ontario. DEAP-3600 began operations in 2016, and the first data is just starting to be analysed. So far, nothing has been found.

WIMP-WATCHING

↓ XENON1T, ITALY

DETECTING: **DARK MATTER**

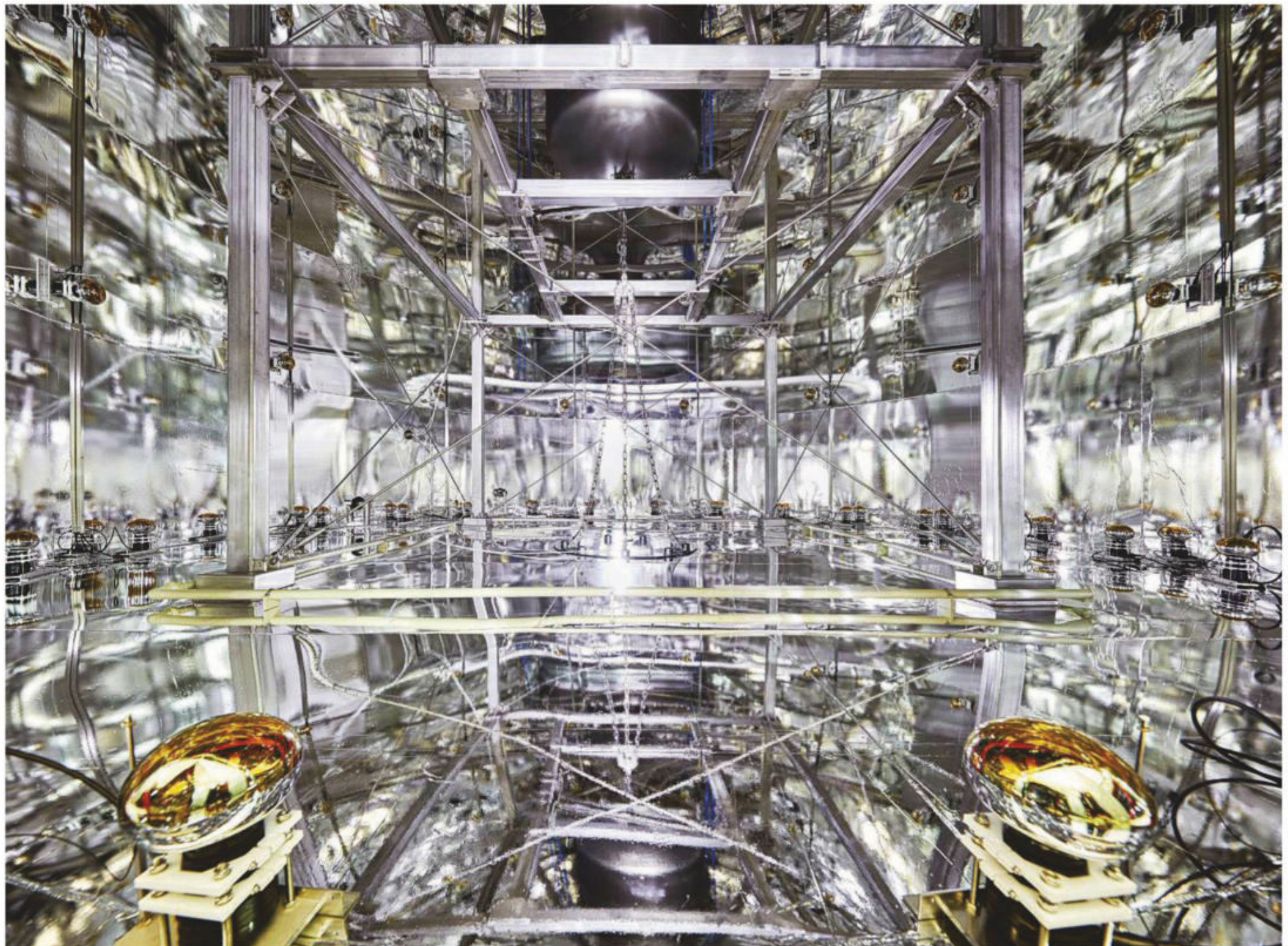
In operation, the 10m-high outer chamber of XENON1T is filled with water, which shields the central part of the experiment from contaminating particles and radiation. Inside this water chamber sits a super-low temperature fridge, known as a cryostat, which houses 3.5 tonnes of liquid xenon. Situated at the underground Gran Sasso lab in Italy, the aim of this experiment is to spot collisions between xenon atoms and hypothetical dark matter particles known as WIMPs, which should produce faint flashes of light. The first results from XENON1T were released in 2017, and as yet no WIMPs have been detected. The researchers are building the next phase of the experiment – XENONnT – which will contain eight tonnes of xenon (giving a greater chance of a collision being observed), and is designed to be more sensitive, thanks to lower background radiation.

by **BRIAN CLEGG**

(@brianclegg)

Brian is a science writer who has authored over 30 books.

His latest is Professor Maxwell's Duplicious Demon (£16.99, Icon Books).



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NEW SECRETS OF THE **SUPERMASSIVE BLACK HOLE**

LAST MONTH, SCIENTISTS UNVEILED A PHOTOGRAPH OF A COSMIC PHENOMENON THAT DEFIES THE LAWS OF PHYSICS, MAKING HEADLINES WORLDWIDE. SO HOW DID THEY DO IT, AND WHAT DOES THIS LANDMARK ACHIEVEMENT ACTUALLY TEACH US?

by **MARCUS CHOWN**
(@maruschown)

ILLUSTRATION: ANDY POTTS

W

Wednesday 10 April was an epoch-making moment in the history of science. At six simultaneous press conferences worldwide, an international team of astronomers unveiled the first ever image of a black hole. “It was one of the most exciting days of my life,” says Feryal Özel of the University of Arizona in Tucson, who heads the modelling team. “For me, it’s the culmination of nearly two decades of work.”

In fact, the team observed two black holes: Sagittarius A*, a supermassive black hole in our own Milky Way weighing 4.3 million times the mass of the Sun, and a cousin in the galaxy M87, which is about 1,000 times bigger. The first image revealed is of the supermassive black hole at the heart of M87. Sagittarius A*, because it’s smaller, was circled by matter many times while being observed, yielding a blurrier picture.

The image of the black hole in M87, since named Powehi, shows detail smaller than the extent of its event horizon, the point of no return for in-falling light and matter. It is only possible to see such exquisite detail because the intense gravity of each black hole acts like a lens, which makes the image appear five times larger than its horizon.

The horizon in M87 shows up as a dark shadow backlit by intense radio waves, emitted by matter heated to incandescence as it swirls down through an accretion disk (gas and dust that is orbiting the object) onto the black hole. The halo around it is brighter on one side than on the other. “This is because the accretion disk is spinning, causing

the light from the part coming towards us to be boosted relative to that from the part that’s receding,” says Özel.

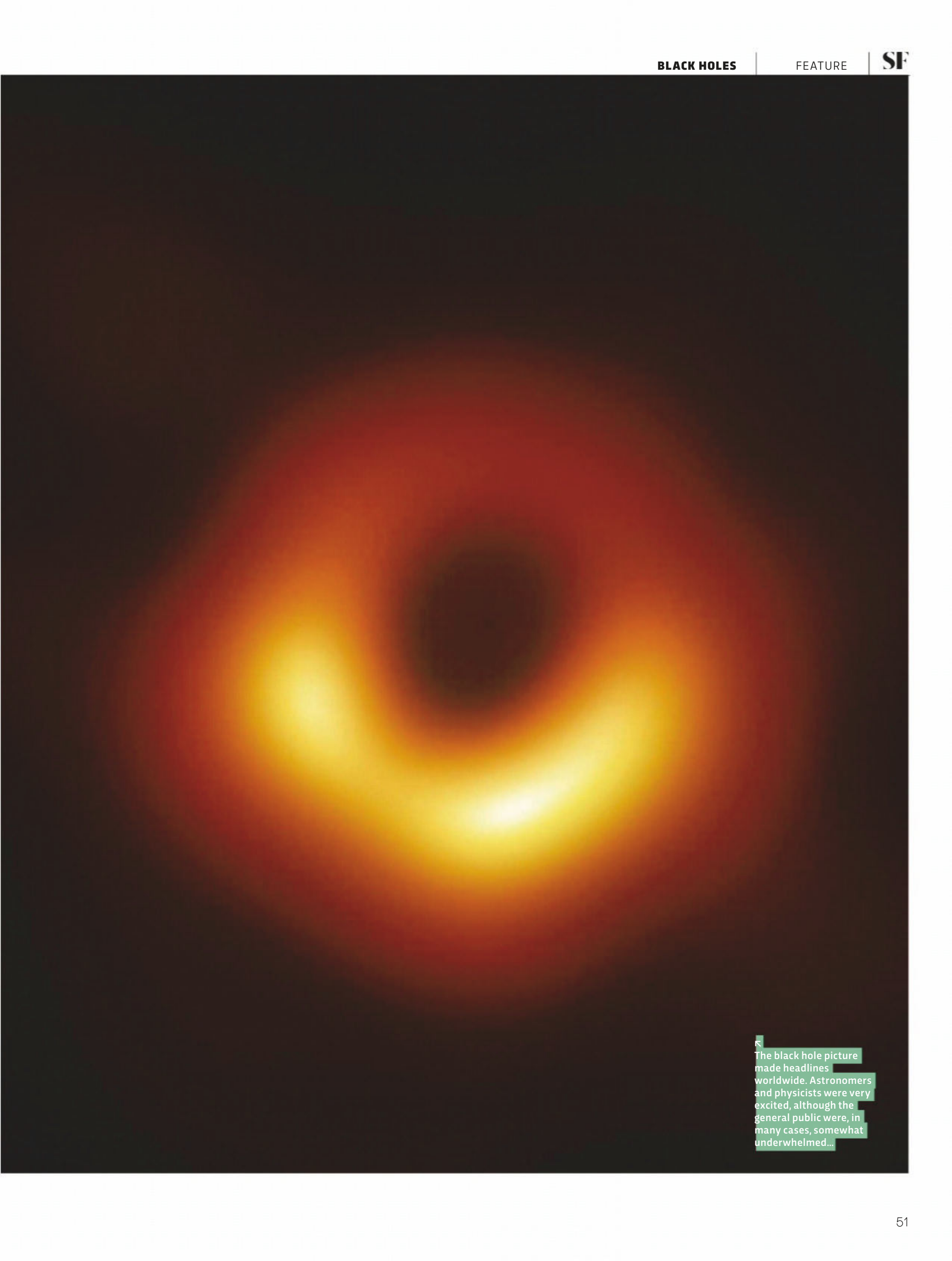
The remarkable M87 image was obtained by the Event Horizon Telescope (EHT), an array of radio dishes scattered around the globe which have been harnessed together to simulate a giant telescope the size of the Earth. Having an Earth-sized telescope is the key to imaging a target as tiny as a black hole, because the resolution of such a telescope – the fineness of the detail it can discern – depends on the maximum separation of its component parts.

STELLAR OR SUPERMASSIVE?

A black hole forms when matter is compressed into a volume so small that its gravity becomes too intense for anything, even light, to escape. This makes a stellar-mass black hole anywhere in our Galaxy too small for us to see with any Earthbound telescope. But nature has seen fit to create a second population of black holes. These are ‘supermassive’ ones with masses of up to 50 billion times the mass of the Sun, one of which lurks in the heart of almost every galaxy. However, on account of being very far away, these behemoths are as difficult to image as stellar-mass black holes in our own neighbourhood. Except in two cases: Sagittarius A*, which is just 27,000 light-years away, and its more massive seven billion solar-mass cousin in M87, at a distance of 56 million light years. “This is why they were chosen as targets for the EHT,” says Özel.

There is also the matter of where to look in the light spectrum. High-energy electrons spiralling in the intense magnetic fields extending from a black hole’s accretion disk generate radio waves, which have the advantage that they can easily penetrate the dust shrouding the centres of galaxies and so reach the Earth. Özel is an

“THE EVENT HORIZON TELESCOPE (EHT) IS AN ARRAY OF RADIO DISHES HARNESSSED TOGETHER TO SIMULATE A GIANT TELESCOPE THE SIZE OF THE EARTH”



↖
The black hole picture made headlines worldwide. Astronomers and physicists were very excited, although the general public were, in many cases, somewhat underwhelmed...

HOW DO BLACK HOLES FORM?

We're still unsure how the supermassive black holes that lurk in the centre of galaxies, such as Powehi in M87, took seed. Some theories attribute their origin to some of the earliest stars formed in our Universe, while others posit their formation by 'dark matter halos'.

We do, however, have a reasonable understanding of how stellar black holes form...

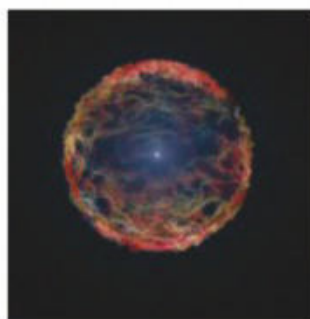
DYING STAR

Once stars run out of fuel, they die in one of two ways. Smaller, Sun-like stars splutter out of existence and form red giants and white dwarfs, while stars 10 or more times larger go supernova before becoming a black hole.



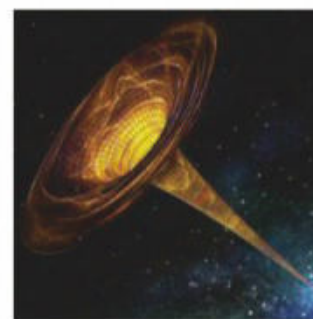
SUPERNOVA

With the fuel spent, the outward pressure of the nuclear reaction can no longer resist the star's own gravity. The remaining material collapses in on itself and implodes in a supernova, spitting material into space.



COLLAPSE

After this violent explosion, gravity pulls the remaining material together. These gravitational forces crush what's left into a singularity: a single point of almost zero volume but infinite mass, and hence infinite density.



BLACK HOLE

All that mass squeezed into an infinitely small point means that the singularity's gravity becomes so strong that nothing, not even light, can escape its pull, giving rise to what we know as a black hole.



BELOW

Kitt Peak National Observatory is the latest telescope to be added to the network of 10 that together constitute the Event Horizon Telescope

expert in simulating what the turbulent environment of a black hole surrounded by a super-heated accretion disk should look like at different wavelengths. "It turns out that the optimum wavelength is 1.3mm," says Özel. "Not only is it possible to see through the accretion disk to the hole,

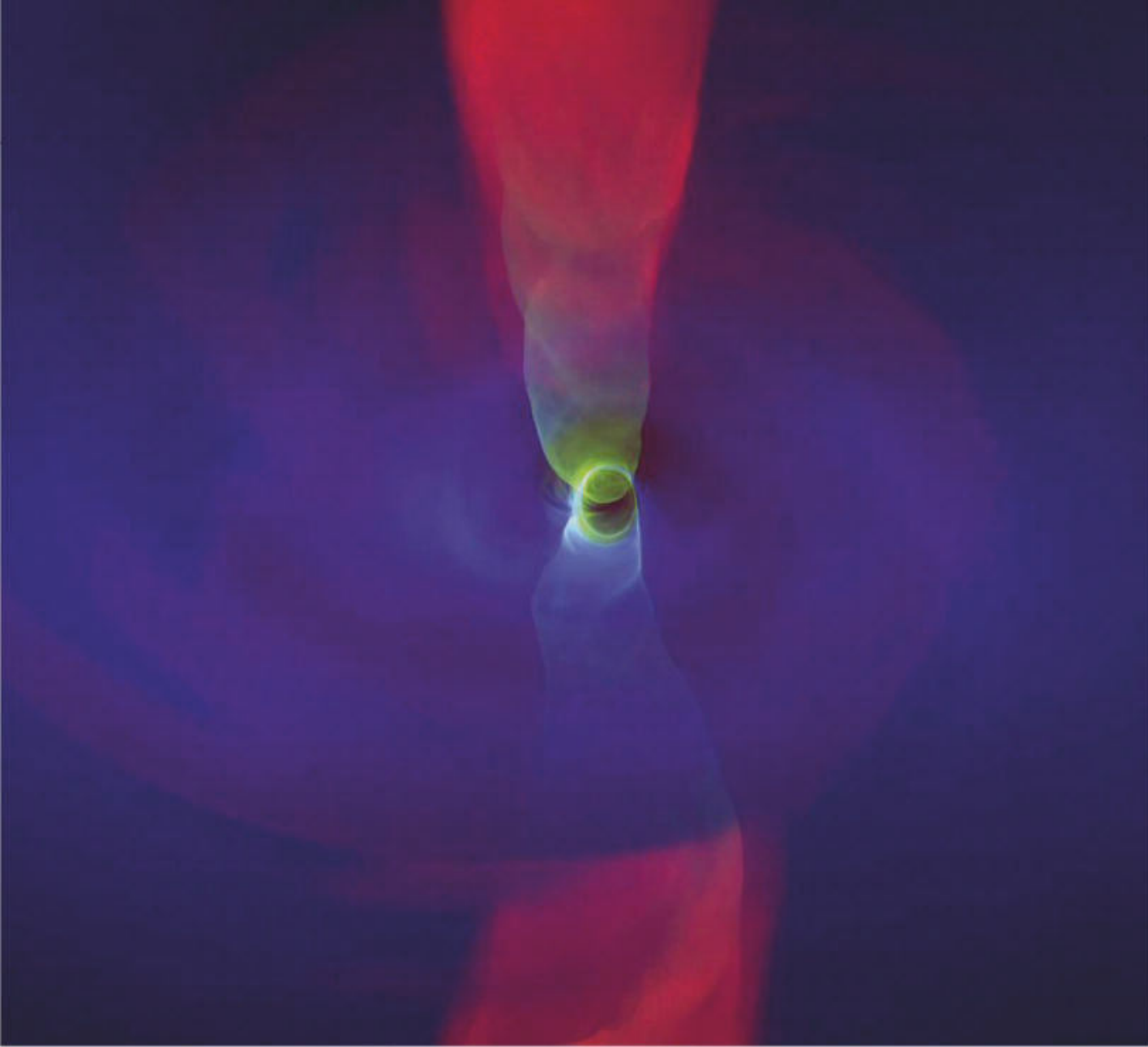
but our Galaxy and the Earth's atmosphere are transparent to radio waves at this wavelength." Despite this wavelength being used, though, water vapour in the atmosphere can still absorb some of the precious radio waves. For this reason, the EHT's astronomers have chosen a time of the year to make observations that maximises the dryness at all telescopes, which are located in places as far-flung as Chile, Hawaii and Greenland. "The optimum time is from the end of March till the end of April," says Özel.

In April 2017, the EHT observed with telescopes at eight sites; in 2018, a dish in Greenland was added, upping the total to nine. Now, with the addition of a radio dish at Kitt Peak National Observatory in Arizona, there are 10, but it's the observations made in 2017 that have yielded the images of Sagittarius A* and M87.

In each observing run, data from each site is recorded on hard drives. Ordinary drives malfunctioned in the low pressure at the high-altitude telescope sites, and had to be replaced by special ones developed for the space programme. In 2017, a total of 960 drives, each with a capacity of six or seven terabytes – capable of storing 1-2 billion photos – recorded a whopping five petabytes of data. The disks, which together weighed more than half a tonne, were flown to Massachusetts and Bonn in Germany, where the signals from each site were combined on purpose-built supercomputers known as 'correlators'.

The individual dishes of the EHT can be considered as tiny elements of a filled-in dish the size of the Earth. But whereas the radio waves impinging on each element of a filled-in dish





off,” she says. “Thankfully, we got the physics right!”

Among other things, the image of the nucleus of M87 has yielded the mass of its black hole. The diameter of a hole’s event horizon goes up by 6km for each solar mass. Consequently, by measuring the width of the hole in the image and knowing the distance to M87, it has been possible to determine that it weighs in at 6.5 billion times the mass of the Sun. “This chimes perfectly with the mass deduced from how fast the hole’s gravity is whirling round nearby stars,” says Özel. “That puts it in the top 10 per cent of black holes by mass.”

Perhaps the most remarkable thing about the image, however, is the sharp ‘photon ring’ that marks the inner edge of the doughnut of light around the hole. This is the point at which light plunges across the event horizon, never to be seen in our Universe again. EHT team member Heino Falcke of Radboud University in Nijmegen, the Netherlands, puts it in perspective: “We have seen the gates of Hell at the end of space and time.”

“The hole is a part of our Universe permanently screened from view,” explains Özel. “A place where our current physics cannot reach.”

Our best current description of black holes is Einstein’s theory of gravity. ●

are reflected to a focus where they are naturally combined, this does not happen for the ‘elements’ of the EHT. The process must be mimicked by playing back the signals on a computer and exactly reproducing the time delays there would naturally have been between them at the focal point.

Getting the signals perfectly synchronised is only possible because at each dish they are recorded alongside clock signals from a super-stable atomic clock. But combining the signals is still hugely time-consuming, because you need to compensate for delays caused by things such as different atmospheric conditions. This is why it has taken so long to analyse the data.

Even this tremendous feat of computing is still only half the job, though. Once that’s been done, it’s still necessary to determine what distribution of matter actually caused the pattern of radio waves observed. “Understanding what’s going on requires figuring out what’s happening over a huge range of scales,” says Özel.

PREDICTIONS PROVED ACCURATE

What’s remarkable is that physicists like Özel have been so successful, and that the image of the black hole in M87 is so close to what they expected to see. But, although this is cause for celebration among physicists, it’s likely to leave laypeople underwhelmed, thinking that they have seen a black hole before. “We are victims of our own success!” admits Özel. “Artist’s impressions and movie simulations of black holes, based on physicists’ predictions, have turned out to be correct. But those holes were pretend ones. The difference now is that we are seeing the real thing.”

Özel says she’s “ecstatic” at being part of the team that obtained the first image of a black hole, but that it’s also a huge relief. “Our predictions could have been completely

ABOVE

Until now, computer generated images like this offered the best picture we had of what black holes look like

“WE HAVE SEEN THE
GATES OF HELL AT
THE END OF SPACE
AND TIME”



LEFT For Feryal Özel, the image unveiled by NASA on 10 April was the culmination of 20 years' work

“STEPHEN HAWKING SUGGESTED THAT GENERAL RELATIVITY MAY BREAK DOWN AT THE HORIZON OF A BLACK HOLE”

● However, the General Theory of Relativity is likely to be an approximation of a deeper theory, since it breaks down at the centre of a black hole, where it predicts the existence of a nonsensical point of infinite density. Such a ‘singularity’ is screened from view by the horizon. The late Stephen Hawking suggested that General Relativity may also break down at the horizon of a black hole, and that the horizon might not actually be the surface of no return everyone believes it to be.

“We have not seen a departure from Einstein’s theory yet,” says Özel, “but finding such a discrepancy would be hugely important.”

Einstein, who never actually believed that black holes could exist in reality, would have both been pleased that his theory has survived, and astonished that such a nightmarish prediction of this theory turns out to be real.

“The fact that Einstein’s theory, formulated in 1915, so accurately predicts what we have seen in such an extreme environment, is a triumph for science,” says Özel. “Until now, the horizon of a black hole was no more than a mathematical formula on piece of paper,” she says. “Now it is a real thing in the real Universe.”

LOOKING TO THE FUTURE

The long-term plan with the EHT is to observe Sagittarius A* and Powehi over many years, to see how they evolve as they swallow gas and rip apart stars. The hope is that we will get to understand things such as how they launch their jets. It is via these channels of super-fast matter – often accelerated to close to the speed of light – that supermassive black holes, despite their relatively tiny size, control the stellar content of their parent galaxies.

“We want to know whether the jets are launched at the horizon and how they are focused and collimated,” says Özel.

In the 1990s, astronomers using NASA’s Hubble Space Telescope in Earth orbit discovered that there is a supermassive black hole lurking in the heart of pretty much every galaxy. Why this is the case remains one of the great unsolved mysteries of cosmology, and it’s one that’s unlikely to be solved by the EHT. Other mysteries also persist. How quickly after the Big Bang were supermassive black holes born? Did they form in the hearts of newborn galaxies, or were they actually the seeds around which galaxies formed? Watch this space!

In the meantime, the first ever image of a black hole may look fuzzy, but sharper images will be obtained in the years to come. Very probably, it will go on to become one of the most iconic images in the history of science, alongside other famous pictures such as the Apollo 8 image of Earth rising above the Moon, or our first glimpse of the double spiral staircase of DNA.

“We humans should be proud of ourselves,” says Özel. “It’s easy to be overwhelmed by everyday events on Earth, but we should take some time to think, ‘We have done this amazing thing. We have seen to the edge of space and time.’” ●

ANATOMY OF A BLACK HOLE

1. ACCRETION DISK

The part of the black hole that gives away its location. Here, stars, gas and any other material nearby spiral towards the hole at blistering speeds, producing enormous amounts of electromagnetic radiation that we can detect here on Earth. The objects sucked into the black hole become more frantic and crowded as they near the event horizon. Some are dragged beyond this point into the hole itself, while others are blasted outwards to create a jet.

2. RELATIVISTIC JETS

Pop culture suggests that nothing escapes a black hole, but that's not quite true. Astronomers have observed jets of particles streaming out of black holes so long and fierce that they break out from their galaxy. To borrow an analogy from Konstantinos Gourgoulatos, a theoretical physicist at the University of Durham, this is like water coming out of a 1cm-wide hose pipe and travelling 80 per cent of the way around the Earth (that's 10,000km).

Our best models suggest that black holes twist the fabric of space-time at their poles. This effect coils magnetic fields, creating a cosmic corkscrew that accelerates particles close to the speed of light before firing them out into the void. At the same time, a magnetic dual-carriageway forms at the black hole's equator – this causes the magnetic field lines to twist and tangle, producing another particle accelerator effect.

These two effects create the fastest particles in the Universe, knocking at the door of the cosmic speed limit: the speed of light. In the long term, data from the EHT should help us understand this comic marvel in better detail.

3. PHOTON SPHERE

As material nears the event horizon, it emits photons (light particles). Normally these would travel outwards in straight lines, but at the cusp of the black hole its gravity bends the photon's path so that we observe a bright ring surrounding a spherical 'shadow'. The EHT will hopefully, in time, reveal more about both.

4. INNERMOST STABLE ORBIT

The inner edge of the accretion disk. This is the final region that material orbits before tumbling past the point of no return.

5. EVENT HORIZON

This is where the black part of the black hole begins. Beyond this point material cannot escape the black hole's grip. More accurately, the escape velocity needed to free itself from the hole's gravitational pull is greater than the speed of light.

6. SINGULARITY

All the matter and energy sucked into the black hole ends up here, at its centre: huge amounts of matter and energy are crushed into an infinitely small space, giving rise to the black hole's gravitational pull. World-renowned theoretical physicist (and science consultant on the film *Interstellar*) Kip Thorne has described a singularity as "a location where the laws of physics break down."



HOW WE KNOW BLACK HOLES EXIST...

WHY HAVE PHYSICISTS BELIEVED FOR SO LONG IN OBJECTS THAT UNTIL NOW HAD NEVER BEEN SEEN?

Karl Schwarzschild was a professor of astronomy at Berlin Observatory who, on the outbreak of WWI, volunteered for the German army. He did not have to: he had a good job and was 40 years old. But he was Jewish, anti-Semitism was on the rise in Germany, and he wanted to prove that he was just as German as everyone else.

Schwarzschild ran a weather station in Belgium, calculated shell trajectories with an artillery battery in France and, at the end of 1915, found himself on the Eastern Front. There, he developed blisters in his mouth. They spread over the whole of his body and he was sent to a field hospital, where he was diagnosed with *Pemphigus vulgaris*, a rare autoimmune disease in which the immune system attacks the skin.

Schwarzschild knew it was serious because the skin is the largest organ. It is through the skin that heat is lost and so, when it is compromised, it is not possible to control body temperature. Also, the skin is a barrier against microorganisms and so, when that barrier is breached, a person is prone to life-threatening infection. The condition remains incurable today, although it can be treated with steroids. But in 1915 there was nothing.

To distract himself, Schwarzschild turned to physics. Back in Berlin, he had been aware that Albert Einstein



“EINSTEIN WAS AMAZED TO RECEIVE A LETTER FROM THE EASTERN FRONT, AND EVEN MORE AMAZED TO FIND A SOLUTION TO HIS EQUATIONS”

was working on a revolutionary new theory of gravity. And when he learned that Einstein had presented it in four lectures in November 1915, he obtained and devoured a written summary.

FROM NEWTON TO EINSTEIN

Isaac Newton imagined that there was a force of gravity between the Sun and Earth, like an invisible tether that kept Earth trapped in orbit. Einstein realised this was incorrect. In fact, a massive body like the Sun creates a valley in the space-time around it, and Earth travels around the upper slopes of the valley like a roulette ball in a roulette wheel.

Einstein had replaced Newton's one equation describing gravity by 10. So working out how space-time is warped by a given mass was very difficult. But, incredibly, Schwarzschild found a formula for the valley-like space-time curvature caused by a spherical mass like a star. He sent it to Berlin. Einstein was amazed to receive a letter from the Eastern Front, and even more amazed to find a solution to his equations,



ABOVE
German astronomer and physicist Karl Schwarzschild

BELOW
Physicist Albert Einstein

which he had considered impossible. The following week he presented the results at the Prussian Academy.

But Schwarzschild had not finished.

EINSTEIN UNCONVINCED

Lying in his hospital bed, Schwarzschild further realised that, if the mass of a star was squeezed into a smaller and smaller volume, the valley of space-time around it would become steeper and steeper until eventually it would become a bottomless pit out of which nothing, not even light, could escape. Today, everyone in the world knows the name of what Schwarzschild had discovered but the term 'black hole' would not be coined for another half century. He again sent his solution to Einstein, who presented it in Berlin, although he did not believe nature would ever implement such a monstrous entity.

In the spring of 1916, Schwarzschild was moved to a hospital in Berlin, where he died. He was just 42.

Fast forward to 1971 and Herstmonceux Castle, the Sussex home of the Royal Greenwich Observatory. Paul Murdin was a young astronomer with a young family to support in need of a permanent job. He needed to make his name – and he had an inkling how to do it.

HELP FROM UHURU

The main problem in astronomy is that the Universe is big. There are two trillion galaxies, each with about 100 billion stars. Finding an interesting one is harder than finding an interesting sand grain among all the sand grains on Earth's beaches. What sign might reveal that a star was unusual?

Murdin hit on X-rays. Such high-energy light

would be emitted by matter heated to millions of degrees. The previous year, NASA had launched Uhuru, the first X-ray satellite, and Murdin obtained the catalogue.

He noticed there was a bright X-ray source, christened Cygnus X-1, in the constellation of Cygnus. The only unusual star in the field was a blue supergiant called HDE 226868, many times the mass of the Sun and pumping out hundreds of thousands of times more light. The star could not be the source of the X-rays – but maybe it was orbiting something that was.

Murdin's colleague Louise Webster was measuring the speeds of stars, so he asked her to measure the speed of the blue supergiant. And, sure enough, she found it was orbiting an invisible companion, once every 5.6 days. From the speed that the supergiant was being whirled around, this companion had to have a mass of at least four, and probably six times the mass of the Sun. The only compact stars that were known – white dwarfs and neutron stars, the latter discovered by Jocelyn Bell only four years earlier – were not massive enough. Only one candidate remained: a black hole.

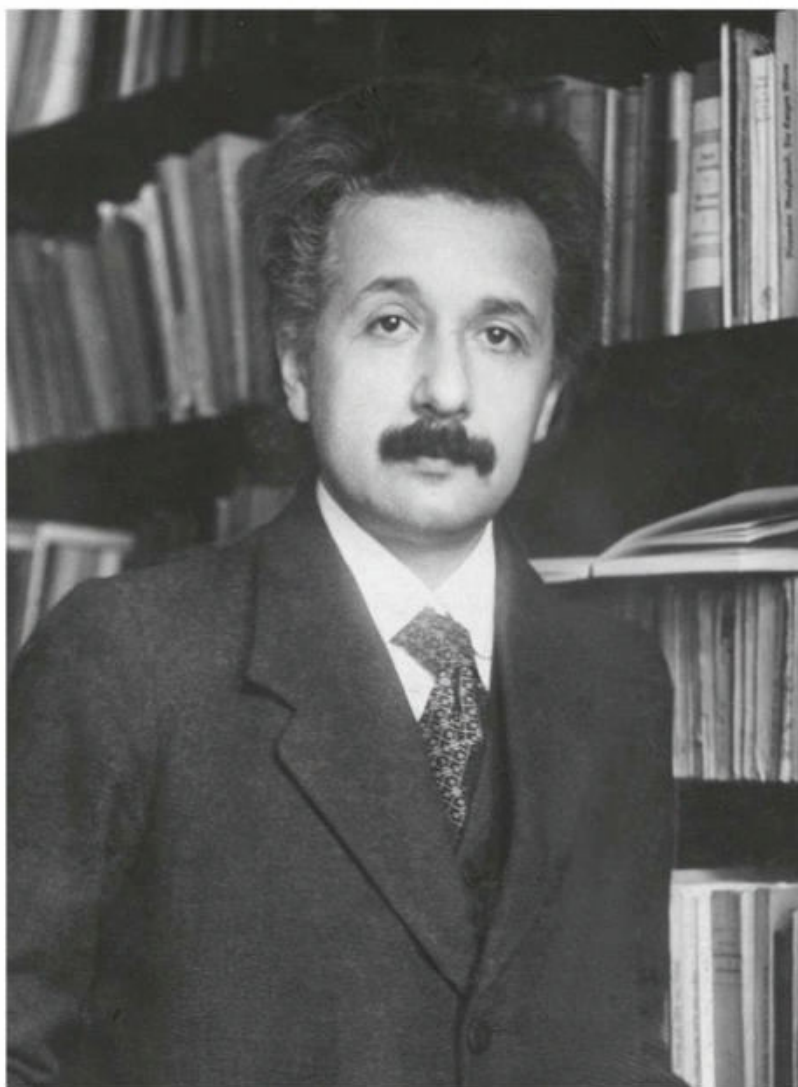
THEORY BECOMES REALITY

Incredibly, the monstrous, nightmare entity predicted by a man dying in a bed in a field hospital on the Eastern Front half a century earlier, actually existed in the real world! It was matter ripped from the blue supergiant and heated to incandescence as it was sucked down onto the black hole that was generating the X-rays. Murdin and Webster wrote a joint paper in the journal *Nature*. Murdin got his full-time job and a new house, and became the first person in history ever to have his mortgage paid by a black hole. **SF**

by **MARCUS CHOWN**

(@maruschown)

Marcus Chown is the author of *Infinity In The Palm of Your Hand: Fifty Wonders That Reveal An Extraordinary Universe* (Michael O'Mara Books, 2018).



UP ALL NIGHT TO GET HAPPY

ON THE EVE OF MENTAL HEALTH AWARENESS WEEK, **HELEN GLENNY** TALKS TO **DAVID VEALE** TO LEARN ABOUT A PIONEERING NEW TECHNIQUE THAT STARVES PEOPLE OF SLEEP TO TREAT THEIR DEPRESSION

HOW DID THIS IDEA FOR A TREATMENT COME ABOUT?

It started in about 1967, when a patient in Germany reported to her psychiatrist that she could treat her depression by going cycling through the night. It was later recognised that it wasn't the exercise that was important, it was the sleep deprivation. Sleep deprivation was then tested: around 50 per cent recovered, but of those about 80 to 90 per cent relapsed. So it didn't really seem to be worth it.

There were quite a few studies and trials that went on in the 1980s and 1990s on sleep deprivation alone, but it became a little sort of footnote in textbooks – 'this is what happens if we do sleep deprivation'. It got forgotten about. It was only in the late 1990s and 2000s that people started to try to work out what can stabilise this response.

Since then, there have been about 12 case series where people have reported on what they'd been doing with their patients, and three randomised control trials where they've compared against a control treatment. And they look very promising: they report that around 50 per cent of people recover, and that's what we've been finding in our research and in our patients so far, too.

WHO IS THIS TREATMENT FOR?

It's for people suffering from depression. It can be either unipolar depression, which means people who have only depression, or bipolar, which fluctuates between mania and depression.

HOW DOES IT WORK?

You're supported to stay up all night, usually in a small group of about four people with an occupational therapist. You come in early Friday morning and don't go to bed until 5pm on Saturday, so you're awake for 36 hours.

With sleep deprivation, about 50 per cent of patients will recover within a couple of days. But the problem is that about 80 to 90 per cent of those that do recover will relapse very quickly, if we can't stabilise it.

SO HOW DO YOU STABILISE THAT MOOD IMPROVEMENT?

We go to what's called 'phase-advance' of one's sleep and bright light therapy. So you've now gone to sleep on Saturday, hopefully, at 5pm. You get eight good hours' sleep, and you get up at 1am on Sunday. That's a tricky time, because it's just very odd. You may feel refreshed, because you've just had eight hours' sleep, but it doesn't feel right because it's still dark and it's the wrong time. So it's very important that you keep yourself active and don't go back to bed, and you stay awake now until 7pm on the Sunday.

Then you're in bed for eight hours, and you get up at 3am on the Monday. You then go to bed the next night at 9pm, and get up on Tuesday at 5am. Then you're back to going to bed at, say, 11pm, and getting up at the normal 7am. And you can't nap throughout treatment: if you nap or fall asleep or whatever during that time, it ruins the effects.

Now we're also going to combine it with bright white light in the mornings. It's something you can have in the kitchen while you're sitting down having breakfast, or reading the paper or using the computer, and it switches off melatonin in the morning. You're essentially creating sunlight – it's the same bright-white light that's used for seasonal affective disorder, but it can also be quite helpful for non-seasonal depression. And you carry on using that for at least another six months or a year, to help stabilise your resetting of the circadian rhythm. ●

BBC

Mental Health Awareness Week (13-19 May)

The BBC is running a series of programmes tackling mental health, including *Alastair Campbell: Depression And Me*. See *Radio Times* for details.



● HOW DO YOU DEFINE 'RECOVER'?

Usually it's defined by at least a 50 per cent reduction in your symptoms.

IS THERE ANY WAY TO KNOW WHO WILL RESPOND TO THIS KIND OF TREATMENT?

We don't really know what predicts who's going to respond well. The problem with the term 'depression' is that it's very heterogeneous. There are many different types of depression, and lots of different symptoms. So, for example, you can have two different patients who score exactly the same on the severity rating scale, but one of them may just get better by themselves within a few weeks, and the other one you know is going to have chronic depression and be very difficult to treat.

Let's say the first one, the easy one, may be a person who has got very good family and social support. Their boyfriend or girlfriend has just left them, perhaps, but they have other things going for them and there's no particular family history of depression. Whereas the other person may have been, I don't know, emotionally or sexually abused as a child, there's a strong family history of depression, and they're now a single parent. You know, they've got lots of other social stressors. These two people may both have the same symptoms of depression, and yet the first one is probably going to get better by herself, and the second one is going to take a lot of help.

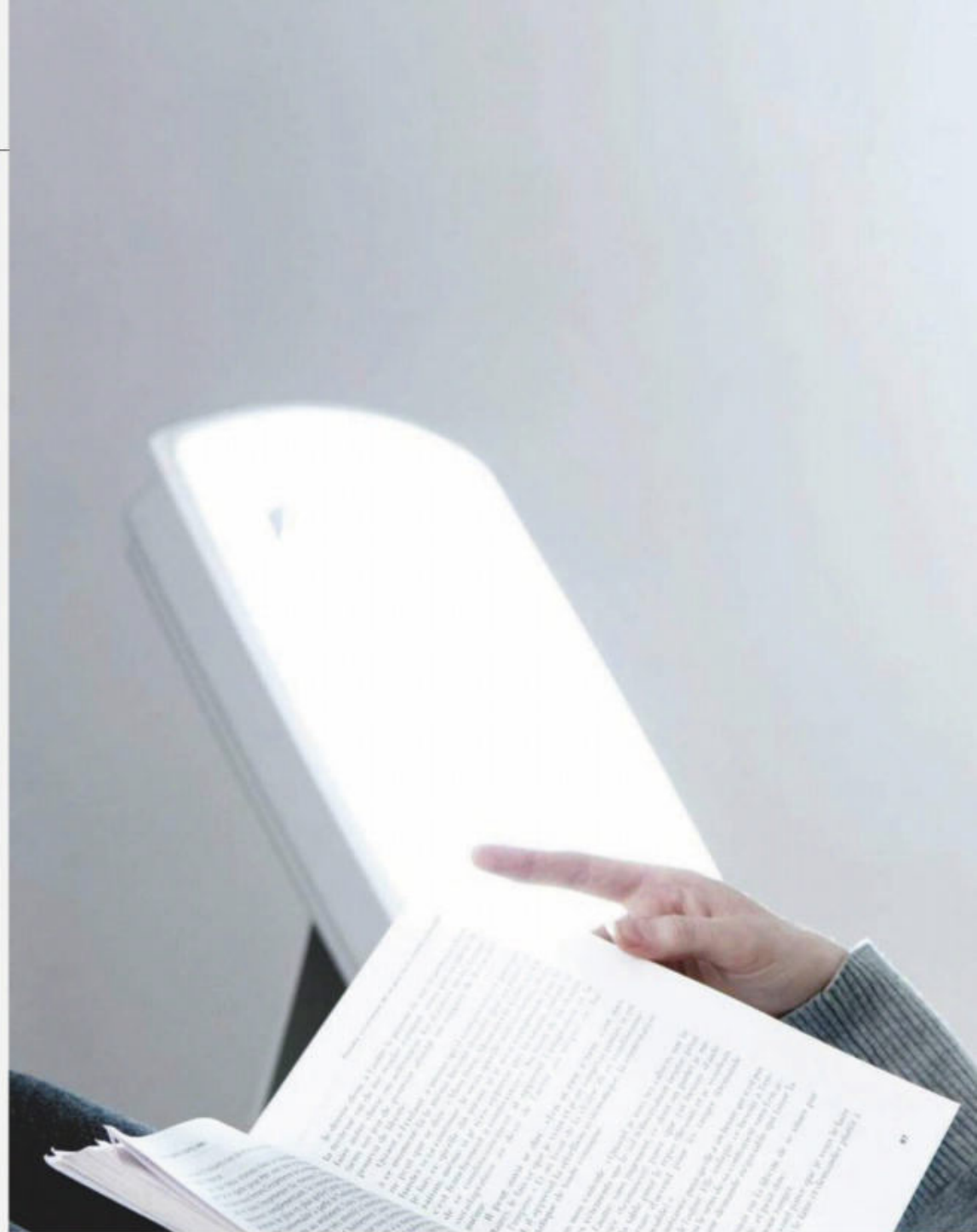
The problem in psychiatry and psychology at the moment is, although we can use terms like 'depression' for communication, they don't really tell us much about what is actually going on, because depression is an end pathway for different types of problems.

But for the large majority of people who have depression, where there is some disruption to their circadian rhythm – they're waking early in the morning, or going to sleep late, or feeling worse in the mornings – wake therapy seems to be particularly helpful. It's especially useful because bipolar depression is quite difficult to treat – antidepressant medication doesn't work that well.

YOU TALKED ABOUT RESETTING CIRCADIAN RHYTHMS – IS THAT, ESSENTIALLY, HOW THIS TREATMENT WORKS?

Yes, some people with depression seem to have disrupted circadian rhythms. That's why their depression's often worse in the mornings.

Melatonin is released at night by the pineal gland, which regulates both your sleep and other hormones. Some people with depression have a disrupted circadian rhythm, and might release melatonin at the wrong time of the day. The idea is



"SOME PEOPLE WITH DEPRESSION SEEM TO HAVE DISRUPTED CIRCADIAN RHYTHMS. THAT'S WHY THEIR DEPRESSION'S OFTEN WORSE IN THE MORNINGS"

that if we can reset the circadian rhythm and melatonin to be released at the right time of the evening, then this can help control symptoms of depression.

HOW MUCH DO WE KNOW ABOUT THE CAUSES OF DEPRESSION?

What presents as depression is probably caused by many things – it's a common final pathway. It's a bit like saying, 'What's the cause of fever?' Fever is caused by many different things. Or what's the cause of headache – that's caused by many different things, too. So we don't know yet, it's very difficult. We can talk at a psychological level



in terms of the way people get caught up with ruminating, or self-attacking or constantly subjugating themselves in a rather submissive way. You could talk at a sociological level, you can talk at a biological level. Another idea that's doing the rounds at the moment is that it's all about inflammation. Again, you'll find that this is probably another sub-type of depression, that not everybody with depression has increased inflammation, and so on.

Of course, we must try and understand what mediates wake therapy and what makes it work. But at this stage, our understanding of things like depression just isn't good enough.

YOU'D THINK THAT DEPRIVING PEOPLE OF SLEEP WOULD MAKE EVERYTHING WORSE...

It does, if it's done intermittently. Across the world, certainly in the UK, if you're an inpatient on the psychiatric ward, and you've been admitted because you're suicidal, you get a nurse observing you every hour or so. And when they do this, they open the door and they come in with a bright torch, and they shine it at you to check you're still alive.

Now, we know from our own research that this causes a great deal of sleep deprivation. And

After sleep deprivation treatment, patients can stabilise their mood by using bright-white light to mimic daylight

when you've got a psychiatric disorder like that, we know that being constantly disturbed actually increases your suicide risk. It makes it harder to tolerate difficult emotions, so it's more likely to lead to increased self-harm. The very things you were admitted onto the ward to keep you safe from! At the moment, sleep deprivation is a major problem on psychiatric wards because of the noise, nursing staff checking on you and so on. And obviously, sleep deprivation is also just a very common experience, isn't it? You can't get to sleep, and it makes you feel worse the next day.

But in somebody suffering from depression, you can do total sleep deprivation on a ward and be supported by staff to stay awake for 36 hours, and then phase-advance the time of your sleep with the light therapy. That's when you see benefits.

CAN THIS TREATMENT GO WRONG?

There are no significant side effects apart from, obviously, some tiredness. There is a slight risk – about 1 per cent – that if you suffer from bipolar disorder, you may become manic if deprived of sleep. But that can be reduced if you're taking a mood stabiliser such as lithium.

Once we get to know who best responds, then hopefully we can target it more, but at the moment, if you don't respond, the worst that's happened is you get tired. It's not a good idea to drive or operate heavy machinery the next day.

HOW DO YOU CHOOSE WHAT TREATMENT TO USE FOR PEOPLE WITH DEPRESSION?

If you are suitable, then I would offer wake therapy first as you'll know whether you are going to get better straight away. Not everyone is suitable for this treatment, and it needs a careful assessment. There are many treatments that have been shown to be helpful: cognitive behaviour therapy, anti-depressant medication, exercise, eating a Mediterranean diet, improving social connections and so on. Some of these approaches overlap, but the trick is knowing which patients will respond to which form of therapy.

IT'S UK MENTAL HEALTH AWARENESS WEEK THIS MONTH. WHAT SHOULD THE PUBLIC KNOW ABOUT DEPRESSION AND BIPOLAR DISORDER?

These are treatable conditions. Don't suffer in silence – seek help. **SF**

WARNING

Please do not try this at home. If you are suffering with depression, or you're worried about someone who is, visit your GP. For more information about mental health, visit mind.org.uk



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COMMENT

THE TRUTH ABOUT BREAKFAST

Does eating 'the most important meal of the day' help you stay slim?

My first talking tour of the UK has just finished, and one of the subjects that has come up a lot is breakfast. Is skipping breakfast a terrible way to start your day? Will you get hungry later, eat all the wrong things and put on weight? That is certainly what Public Health England and NHS guidelines currently say. But is it true?

There is plenty of evidence from cohort studies that eating breakfast is good for your health. A study last year from the German Diabetes Centre in Düsseldorf, for example, found that when they compared a group of people who skipped breakfast with a group who ate breakfast, those who skipped it were not only heavier but were also 33 per cent more likely to have type 2 diabetes than those who didn't.

But just because people who skip breakfast tend to be less healthy, it doesn't mean that breakfast is the reason. The fact is that people who regularly eat breakfast also smoke less, drink less and tend to be more active than those who skip breakfast, factors which are likely to be of much greater importance than when you decide to break your fast.

The best way to resolve the question is to do randomised controlled studies in which you ask breakfast skippers to eat breakfast, and vice versa, and see what happens.

✕ "Caution is needed when recommending breakfast for weight loss in adults"

The good news is that a large number of these studies have been done. The bad news, for the advocates of 'breakfast is the most important meal of the day', is that randomised controlled trials have, on the whole, shown that getting people to eat breakfast can be counterproductive.

A large meta-analysis recently published in the British Medical Journal pulled together results from a dozen studies. It found that although people who skip breakfast do eat more later in the day, they don't eat

enough to compensate for the calories they skipped early on.

In fact, the scientists found that people who are asked to skip breakfast eat, on average, 260kcal less a day than those who eat it. They also weigh, on average, 0.44kg less. The researchers concluded that, "Caution is needed when recommending breakfast for weight loss in adults, as it could have the opposite effect."

Prof Tim Spector, of King's College London, who wrote an accompanying blog, went further. He not only queries the benefits of making people eat breakfast, but also points out that the alleged benefits for children are, "weak, largely observational, and likely biased in the same way as for adults".

So the message is, if you enjoy eating breakfast (as I do), then fine. But if you prefer to wait and break your fast later in the day, then no harm done. **SF**



MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *The Fast 800* (£8.99, Short Books).



COMMENT

IT WASN'T ME!

Why scapegoating and finger-pointing don't help anyone

The last few years in global politics have been chaos; the cacophony of politicians trying to outperform each other in various absurd zero-sum conflicts – from Russian interference in the US 2016 presidential election to who was responsible for the British economic crisis – is deafening.

It really doesn't matter if you're on the left or the right or somewhere in the middle, conversation has turned from public service to public humiliation. International debates have reduced complicated concepts of national identity, economic stability, resource management and other high-level ideas to blaming and scapegoating.

The official line on scapegoating dates back to Leviticus, when he wrote about the practice of taking two goats, killing one as a sacrifice to the gods, then ritually burdening the other one with our sins, before banishing it into the desert and away from the apparently squeaky clean citizens of Blameville.

Nowadays, most of us don't keep extra goats around just in case we need to send them away. Nonetheless, politicians demonstrate on a daily basis how easy it is to blame, shame and discard people who've previously been close confidantes. In November 2018's issue of the journal *Religions*, Prof Kathryn McClymond describes how Donald



“Rather than pointing fingers of blame, we can accept our part in the plot, and turn down the noise”

Trump has repeatedly deflected attention away from himself onto anyone who happens to cross his path, including his own son.

Here are a few tips about using this technique to get yourself out of a sticky situation. They come from Burcu Savun and Christian Gineste, two researchers who wrote about the politics of scapegoating between 1996 and 2015 for the December 2018 issue of *The Journal Of Peace Research*. Number one: the best scapegoats are those who can't fight back. Choose the powerless. Or outsiders. Or immigrants. Number two: the best time to transform these folks into the face of your problems is immediately after some kind of

national threat. This primes the pump for political decision-making that loosens legal responsibility for these sorts of people. For example refugees – of any nationality – are more likely to be physically assaulted, and it's doubtful their attackers will be punished.

But before you panic about the terrible state of modern humanity, remember, we all go through an “it wasn't me!” phase, usually in childhood. Separating the bad thing from the self is part of what we have to go through to get a sense of personal responsibility. As we grow up, *most* of us learn that getting away with something may feel good, but it doesn't bring about world peace.

So perhaps this is the moment we should take personal responsibility. Most of us have a digital platform, and a potential audience. Let's show the politicians who are, frankly, doing a terrible job of leading by example, what it means to be an adult. Rather than pointing fingers of blame, we can accept our part in the plot, and turn down the noise. **SF**



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RETHINKING DEMENTIA

By 2025, the number of people living with dementia in the UK is expected to exceed one million. What can be done to help them? New research shows that having a job and getting involved in creative projects could be the answer...

by JHENI OSMAN

“What ice cream flavours have you got for dessert?”

*“Hazelnut. Or strawberry and... erm, I’ve forgotten!
Let me just go and check.”*

Joy heads off to the kitchen, returning a minute later.

“Strawberry and white chocolate.”

So far, so normal. What waitress or waiter doesn’t forget the odd detail on the menu? In fact, our whole meal has been completely hitch-free. Nothing amiss, no spillages... not bad going for a place that calls itself The Restaurant That Makes Mistakes.

This is no ordinary restaurant. It’s run by Michelin-starred chef Josh Eggleton, and all 14 of his chefs and waiting staff are volunteers living with dementia. The pop-up restaurant is the brainchild of CPL Productions, which is filming a Channel 4 series looking at how people with dementia might benefit from staying in work. Celebrities such as *Downton Abbey*’s Hugh Bonneville have already stopped by for a slap-up meal.

I tucked into mushrooms with lovage, followed by ox cheeks with gratin, then finished off with the aforementioned ice cream. If I didn’t know in advance – and turned a blind eye to the TV camera lurking behind a curtain – I’m not sure I would have

noticed anything different about this restaurant.

The volunteers have certainly risen to the challenge. But it hasn’t all been plain sailing. “It’s been stressful, because I’ve had good days and bad days,” Joy tells me. “On a bad day, I can’t think straight, my head is foggy, and everything I do takes 10 times longer. To actually plan anything some days is impossible. Other days, I can get through and enjoy every moment. Today is a positive day.”

NEW PURPOSE

Some 850,000 people are estimated to be living with dementia in the UK, and that’s expected to rise to two million by 2050. Most of us probably know, or have known, someone with dementia. But we may not understand the difference between dementia and, say, Alzheimer’s disease. Dementia describes the *symptoms* that someone experiences as a result of a brain disease. Such symptoms can include memory loss, mood and behavioural changes, and difficulties with ►



● thinking, problem-solving and language. More than 100 diseases can cause dementia, each with slightly different symptoms.

The most common cause of dementia is Alzheimer's, which is what Joy has been diagnosed with. After diagnosis, she had to give up her job working in care. "Having looked after people with dementia, I knew exactly what I could be facing," she says.

Joy is not alone in losing her job in the wake of her diagnosis. Of the 40,000 people with dementia in the UK who are under the age of 65, only 18 per cent carried on working after they were diagnosed. By 2020, one-third of the UK workforce will be 50 or over, and many will go on to develop some kind of dementia. Rather than having to leave their job, could these people be better integrated into their workplace? One of the goals of the Channel 4 series is to encourage employers to take on staff with dementia, or keep current employees after a diagnosis.

"Many of the volunteers admitted to feeling isolated and unsupported by the welfare system, feeling like they'd been thrown on the scrapheap," says Louise Bartmann, producer of the series. "After a diagnosis, many of them lost their job, their ability to drive, their independence, their identity and, in some cases, their friends and family. The restaurant has given the volunteers a sense of purpose."

To cater for the volunteers, the restaurant made some small adjustments, such as labelling objects like the coffee machine and the cutlery tray. To help locate their belongings in the staff room, each volunteer has a photo of themselves on their locker. They're also each given a notebook, so they can write things down, such as recipes and what items need to be laid on the table, as well as 'memory books' to help them remember things like the names of their colleagues.

"The volunteers say they feel more confident," says Bartmann. "For some, this is demonstrated through their verbal fluency, whereas for others it is being visibly happier."

"I think it's important that everyone realises that we can't do stuff on certain days," says Joy. She is quick to sing the praises of the support offered by the television team. "There's always someone on hand for us. One day, I fell apart and there was someone there within seconds. We've got a chaperone at the hotel overnight [to ensure the volunteers are looked after away from home]. The

team's vision has been second to none."

The Alzheimer's Society has drawn up a guide for employers to help them integrate workers with dementia. Suggestions include changes such as making signs clearer and improving acoustics, as well as less tangible things such as carrying out surveys to find out how many of the staff are actually affected. And, crucially, being careful with language – avoiding phrases such as 'dementia sufferer', 'demented' or 'burden'.

As The Restaurant That Makes Mistakes has shown, having a job and feeling useful can be hugely beneficial to people with dementia. But research has found that it can also help to do something creative – whether that's through music or art.

CREATIVE THINKING

Dementia can cruelly rob people of their ability to communicate properly. However, people with dementia whose language skills have failed can still use art as a tool to communicate with loved ones, according to a 2013 study at St Michael's Hospital

Joy, one of the staff members at The Restaurant That Makes Mistakes



40,000

The number of people under 65 living with dementia in the UK



7,200 employed
32,800 unemployed

“MANY OF THE VOLUNTEERS ADMITTED TO FEELING ISOLATED AND UNSUPPORTED”

in Toronto. In the case of Alzheimer's disease, some researchers believe that art therapy may enable people with dementia to communicate using regions of the brain that have remained relatively healthy.

In 2016, a group of scientists, artists and musicians set up a two-year initiative called Created Out Of Mind at London's Wellcome Collection, with the aim of using the creative arts to explore and challenge people's understanding of the different types of dementia. Over the course of the two years, more than 1,000 people with dementia benefited from its variety of artistic and musical experiences. One of the projects worked with people living with a rare form of dementia called posterior cortical atrophy (PCA). PCA is

CHANNEL 4 TELEVISION, GETTY IMAGES

WHAT IS ALZHEIMER'S DISEASE?

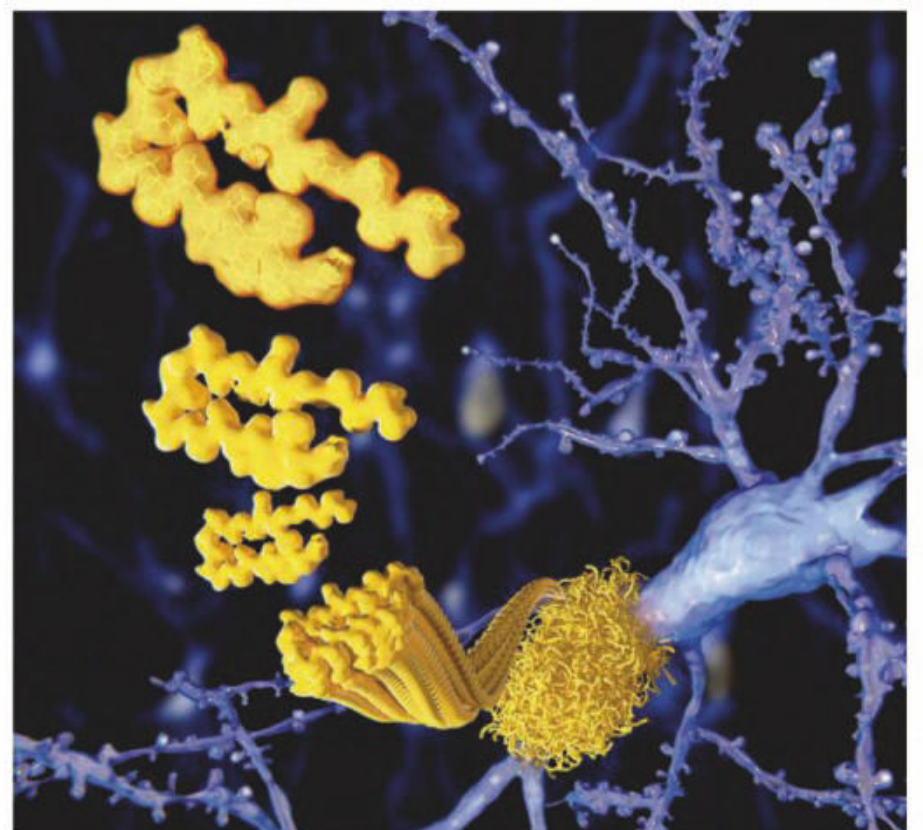
Of the 850,000 people living with dementia in the UK, around two-thirds have Alzheimer's disease, making it the most common cause of dementia. It's associated with a build-up of proteins in the brain, which accumulate into tangled structures called 'plaques' (illustrated below). These disrupt communication between nerve cells, eventually killing the cells entirely. The disease also causes a lack of some key chemical messengers in the brain, which further disrupts communication between nerve cells.

The first symptoms of Alzheimer's are often short-term memory problems, but it's a progressive disease and the symptoms worsen and widen over time. Someone might go on to develop

problems with language, reasoning, concentration, mood or spatial awareness.

"Problems within the brain may start about 20 years before any symptoms appear," says Dr Shelley Allen-Birt at the University of Bristol, whose work focuses on the molecular mechanisms of Alzheimer's. "To diagnose the disease before people show symptoms is quite a challenge. We are devising ways of looking at early changes in the brain – through brain scans and biochemical markers in the blood and cerebrospinal fluid – which could help us to spot the disease early."

There are no cures for Alzheimer's disease, but there are drugs and a great deal of support available to help those living with the condition. Visit alzheimers.org.uk



● caused by shrinkage at the back of the brain, which can lead to visual problems such as trouble with recognising faces and judging distances. It is difficult for people to communicate the experience of these problems to others: they can't just amend a photo to show what their world looks like. Through the Created Out Of Mind project, a filmmaker interviewed people living with PCA and created an animation called *Do I See What You See?* The animation was a success: one woman, whose husband lives with PCA, showed it to the hospital staff looking after him while he had a hip operation, and it helped the nurses tailor their care to his needs.

Another project used technology to gather data on how music can help. Singing With Friends is a choir made up of people with dementia. Choir members were asked to wear wrist sensors to monitor their heart rate and skin conductance, which is a measure of arousal. The results are still being analysed, but initial feedback supports what everyone involved in Singing With Friends can see: singing has a positive physiological effect on people with dementia. This also ties in with research showing that singing in choirs more generally can improve mood and wellbeing.

"People with early-onset Alzheimer's disease, for example, often have brain impairments in coding new information, but their emotional processing systems are still very much intact," says Prof Sebastian Crutch, a neuropsychologist at University College London and director of Created Out Of Mind. "So why wouldn't those people be given the opportunity to take part in a choir? They may not be able to recall the factual details of exactly what happened and when, but they frequently make statements like, 'I remember how I felt'."

MUSIC FOR THE MIND

Indeed, there is a growing body of evidence that shows music can significantly improve the lives of people with dementia. A study carried out last year at the University of Utah found that music stimulates various areas of the brain simultaneously, including parts which are the last to be affected by dementia. Back here in the UK at the University of Worcester, meanwhile, doctoral researcher Ruby Smith is finding that compiling music playlists can help people with dementia to connect with others in their lives.

"Music maintains a kind of neural robustness in the brain, and there are still



1. Music and dance workshops by the Created Out Of Mind project, at the Wellcome Collection

2. Sadly, The Restaurant That Makes Mistakes isn't a permanent venture: it was housed for a month in a restaurant called The Kitchen, located in a disused fire station

3. Various celebrities visited during the restaurant's brief tenure, including Hugh Bonneville from *Downton Abbey*

THE SEARCH FOR A CURE

There is currently no treatment to halt dementia, but here are some promising avenues...

Bacteria blockers

The bacteria that cause gum disease could contribute to the development of Alzheimer's. A recent study published in *Science Advances* found DNA and enzymes from *Porphyromonas gingivalis* bacteria in the brains of deceased people who'd had Alzheimer's. It's unknown how the bacteria get there, or how they affect the brain, but it's a link that could pave the way for Alzheimer's treatments that block toxic enzymes secreted by these bacteria.



2



3

CHANNEL 4 TELEVISION X2, DAVID SANDISON/WELLCOME

often some fairly strong links between music and memory,” she says. “Memories evoked by hearing music or humming a familiar tune can help people to reminisce about their past, opening up new conversations and friendships.”

A recent House of Lords inquiry looked into the untapped potential of music to enhance the wellbeing of people living with dementia. Off the back of this, the Music for Dementia 2020 campaign is asking the Department of Health and

Social Care to enable music to be ‘socially prescribed’. In other words, instead of being given medication, which may have a limited effect, someone with dementia might be teamed up with a local music therapist, or offered access to a music group or choir.

CHALLENGING PERCEPTIONS

The key message of all these different projects seems to be that cultural perceptions need to change so that people living with dementia can reap the benefits of being better integrated in society, whether that’s through work or the arts.

“We need to break down any taboos or stigma about what dementia is or isn’t, and that includes that it’s only a disease for old people,” says Tim McLaughlin, operations director at the Alzheimer’s Society. “Let’s make sure that, before dementia takes away these people’s individuality and independence, society does not remove them first.”

Crutch agrees: “Frequently, people living with dementia talk about a sense of social disconnection. They get a diagnosis and, suddenly, they’re talked about as a patient, not a person. The key is to encourage the public to think twice about what opportunities people with dementia might be given, so that they can continue living as the people they are and will be – not just the people they were.” **SF**

by **JHENI OSMAN** (@jheniosman)

Jheni is a science writer and broadcaster, presenting BBC Radio 4’s Costing The Earth.

DISCOVER MORE



The Restaurant That Makes Mistakes will be shown on Channel 4 in June. Check Radio Times for details.



For more on the positive effects of music, watch *Our Dementia Choir With Vicky McClure* on BBC One in May.

Gene therapy

This method either replaces a mutated, disease-causing gene with a healthy version, stopping it from functioning, or introduces a new, disease-fighting gene. Research shows that people with a gene variant called APOE e4 have a higher risk of developing Alzheimer’s, so using gene therapy to replace or ‘knock out’ this gene could help. Other research suggests that a variant of the PLCG2 gene may reduce the risk of developing certain types of dementia, including Alzheimer’s disease.

Protein preventers

Last year, scientists from the University of Cambridge and Lund University in Sweden identified the toxic clumps of proteins that destroy healthy brain cells in Alzheimer’s disease. The researchers now hope to develop drugs to target these protein deposits, preventing them from forming in the first place. The aim is to bring the first drugs to clinical trial in the next couple of years.

Repurposed drugs

Researchers in California recently found that a gene responsible for making toxic proteins involved in Alzheimer’s reshuffles its DNA more in those people who have the condition. This may be why drugs have limited success – they can’t target the range of proteins produced. This ‘shape-shifting’ seems to be linked to enzymes called ‘reverse transcriptases’, so the team is investigating whether HIV drugs that block these enzymes could help with Alzheimer’s, too.



SHOULD MEDICINE BE GENDERED?

Men and women have completely different biologies, and yet doctors prescribe the same drugs and doses to everyone, regardless of sex. The results can be damaging, even deadly. Is it time that medicine treated men and women differently?

by SIMON CROMPTON

The sleeping tablet Ambien is a blockbuster – it's one of the most commonly used insomnia and jet lag treatments in the world. Yet a decade or so after its approval in 1992, worrying reports began to emerge. Users – particularly women – were behaving bizarrely after taking the sedative, then having no recollection of what they'd done. There were accounts of people being involved in driving accidents the morning after taking the tablets.

Research confirmed that women were more likely than men to have bad side effects after taking Ambien. Then, in 2013, US drug regulators confirmed there was a problem: the manufacturer's recommended dose was double what it should be for women. The research leading up to the drug's launch had not separated out men and women, so it had taken two decades of public use to recognise that women metabolised Ambien at a significantly slower rate than men. The result was that when they woke up, they still had the drug in their system, leaving them drowsy, confused and liable to have a car crash.

If it seems odd that the possibility of different drug doses for women wasn't considered as a matter of course 25 years ago, then it's remarkable that this is still the case. Only in the past decade has the idea that women may need different treatments from men gained a foothold in mainstream medicine. Far

from being a minority feminist movement riding the wave of #MeToo awareness, the new field of gender medicine is rebuilding medicine from the foundations of sound science. In the process, it may transform men's health too.

SEX MATTERS

Medicine has long worked on the assumption that women are essentially men with boobs and tubes – and so 'women's health' became a term associated with the reproductive organs. It was only at the dawn of the 21st Century, with the emergence of evidence that women were experiencing heart attacks entirely differently from men, that the old 'bikini medicine' outlook began to be seriously challenged.

Heart researchers found that all those supposedly 'classic' symptoms – a tight pain in the chest, shooting pains down the arm, dizziness – were actually male symptoms. Women experience other signs such as shortness of breath, fatigue, nausea, and pain in the jaw or back. Yet these symptoms, which may be down to different patterns of obstruction in women's coronary arteries, were not in the research literature, and were not being recognised by doctors. Women were dying of heart attacks as a result.

In the two decades since, a cascade of evidence has emerged indicating the deep-seated differences in male and female biology, and the need for different approaches to diagnosis and treatment. ●

● For example, women have a faster and stronger immune response than men (so men are significantly more likely to die of infectious diseases), but women are more likely to have autoimmune diseases such as rheumatoid arthritis. Women's and men's metabolism, experiences of pain, and likelihood of developing Alzheimer's disease are all different.

Here, it's worth pointing out that sex and gender have different meanings, but are closely linked. 'Sex' refers to the biological differences between males and females. 'Gender' refers to a person's characteristics or identity as shaped by society and the environment as well as biology. Gender medicine embraces *both* meanings, considering how women's environment also affects their health and the way they are treated.

The differences between the sexes begin before birth, with male and female sex hormones such as testosterone and oestrogen helping mould brain and organ development from the embryo onwards. "Women experience constant fluctuations in hormones through every stage of life, which is an important difference from men, and has major implications for their health," says Prof Alexandra Kautzky-Willer, head of the Gender Medicine Unit at the Medical University of Vienna.

The differences come right down to the sub-cellular level. Every cell, male or female, contains around 20,000 genes. Although these genes are virtually identical between men and women, research published by Israel's Weizmann Institute of Science in 2017 found that around a third of them are activated ('expressed') differently in men and women. For example, the researchers found that the highly expressed genes

BELOW Medicine could soon be getting a shake-up, to offer more products specifically tailored to men's or women's biology



F

GENDERED BODIES

FIVE KEY MEDICAL DIFFERENCES BETWEEN MEN AND WOMEN



INFECTIONS

While the male sex hormone testosterone (crystals of which are pictured above) tends to dampen the immune system's response to infection, the female sex hormone oestrogen increases the number of immune cells and the intensity of their response. 'Man flu' may be a manifestation of men's struggle to fight off infection.



IMMUNE SYSTEM

Women are more likely to suffer from diseases characterised by the immune system attacking its own body – conditions such as lupus, rheumatoid arthritis and multiple sclerosis. Around 78 per cent of those affected by autoimmune conditions are women.



PAIN

Research consistently shows different experiences of pain in men and women. Women are generally more sensitive and less tolerant to painful stimuli. Surgical research suggests that this may partly be due to them having a greater number of nerve receptor cells in the skin.

in men's skin were related to body hair growth. In all, there are an enormous number of factors at play. "Gender health differences are the result of differences in genetic makeup, hormones, epigenetics – the effects of the environment on gene expression – and social factors," says Kautzky-Willer.

Kautzky-Willer's research specialises in diabetes, and she has found that men are more vulnerable to the condition

later in life if their mothers endured hardship during pregnancy. She is also investigating whether separate blood tests are needed for men and women to diagnose diabetes and heart attacks. On the basis of new discoveries about differences in male and female blood chemistry, she is seeing an increasingly compelling argument that they are.

"There probably need to be different cut-offs or even different biomarkers for the same diseases," she says. "Currently, to diagnose diabetes, you do an average blood glucose reading – HbA1c – plus a fasting glucose blood test. But we now know that women usually have lower fasting glucose and HbA1c readings than men, and you're more likely to find women at risk if you additionally do an oral glucose tolerance test."

BIASED MEDICINE

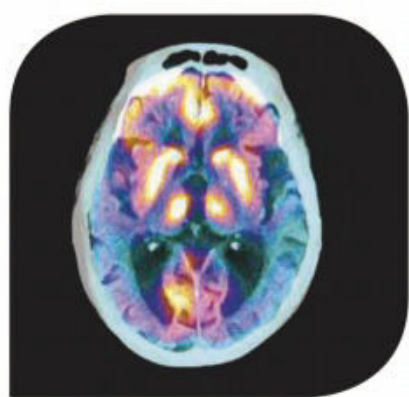
Similar realisations about the need for sex-specific tests and treatments are happening in virtually every field of medicine. There's evidence that many heart medications and anti-sickness drugs are less effective in women than men; that women are more sensitive to antihistamine drugs; that aspirin is more effective at preventing strokes in women, yet more effective at preventing heart attacks in men; that it can take women twice as long to digest medications.

The differences are clearly a matter of life and death. Though experts are reluctant to specify how many women might have lost their lives prematurely as a result of symptoms not being recognised, or inappropriate tests and treatment being administered, they do not baulk at the suggestion of hundreds of thousands.

How could this arise? How can medicine have been working for so long on the principle that women are the same as men?

The answer is that, until now, nearly all research – whether basic science on cells and animals, or trials of new drugs on humans – was carried out on males. A 2010 study from the Duke Clinical Research Institute in the US found that only a quarter of those involved in coronary artery disease trials are women. Dr Alyson McGregor, associate professor of emergency medicine at Brown University in the US, says that medical science over the past century has

"MEDICAL SCIENCE OVER THE PAST CENTURY HAS BEEN BASED ON ONLY HALF THE POPULATION"



BRAIN CONDITIONS

More women suffer from Alzheimer's, and symptoms differ. Women often display behavioural changes and depression, while men show physical impairment and aggression. Mental illness also differs. In bipolar disorder, for example, women are more likely to have 'mixed' manic and depressive episodes than men.



GUT FUNCTION

It can take women twice as long as men to digest food and medications. Women are more likely to suffer from gallstones (calcified gall bladder shown in red above) and irritable bowel syndrome. And female smokers are at greater risk of colon cancer than male smokers, according to recent Norwegian research.

● been based on only half the population. Doctors like herself have routinely ordered the same tests and medications regardless of the patient's sex, because they were never taught to do otherwise.

The reasons for this are more complex than the undoubtedly male-dominated history of medicine, she says. In the early 1970s, there were influential legal moves in the US to protect vulnerable groups, such as women of childbearing years, from potentially harmful testing.

"It sort of eliminated women from being enrolled at all into scientific studies," says McGregor. "And there was this general assumption at the time that women and men were similar enough, so people said, 'let's study men and take the results and generalise them to everyone'. That's how a lot of our original research was established."

Then in the 1990s came legal moves to make trials more representative by including women. "But that's not good either," says McGregor, "because if you're just mixing the results they won't be applicable to either men or women. Some studies have shown that a drug has a positive effect on men and a negative effect on women. But if we just combine the results we will never discover those differences and will have lost important clinical meaning."

TURNING TIDE

Leaders in gender medicine such as McGregor and Kautzky-Willer believe that a revolution in medical research is now required, so that data for women and men is systematically and separately gathered in every trial for every drug or treatment.

Cost is a significant barrier: one reason why drug researchers have been slow to pick up on gender medicine is that it is more expensive to have women in trials than men. It's because of their hormonal fluctuations: for every time a man's response to a drug needs to be checked, a woman's will need checking several times according to where they are in the menstrual cycle. Using female mice is more expensive for the same reasons: a 2011 study from the University of California found that animals in medical research are five times more likely to be male than female.

SAME DRUGS, DIFFERENT RESULTS

There are many characteristics apart from gender that can affect how well a medicine works for someone



AGE

In infants and older people, the liver and kidneys may work less effectively, so drugs aren't broken down so well and tend to accumulate in the body's tissues, prolonging their influence and increasing the risk of side effects.



ATTITUDE

There's evidence that people with an optimistic outlook respond better to painkillers, due to a stronger placebo effect. Your expectations of whether a drug is going to work, based on past experiences, can also influence its effectiveness.



BODY SIZE

A larger person generally needs more of a drug than a smaller person needs for the same effect. Research indicates that standard doses of antibiotics, fertility drugs, birth control pills and emergency contraception may not be effective in people who are obese.



GENERAL HEALTH

Other diseases can affect how well a drug is processed in the body. If you're taking other medicines, these may interfere with how a new medicine works. And if you've taken a medicine for a long time, you may become tolerant to it.



GENES

Genetic variations in the population ('polymorphisms') are increasingly understood as one of the main reasons why some drugs work better on some people than others. They influence how well a drug is broken down by enzymes.

"But there's a moral obligation to study both men and women [regardless of cost], and there's also the potential cost to consider of having to withdraw a drug when you find it's harmful to women after you've spent a billion dollars getting it to the market," says McGregor. "I feel that change is inevitable now. Researchers need to design their studies to determine whether there are sex-based differences, and then their funding agencies need to ensure that possible sex differences are always taken into account. Review boards, journals, and peer review systems must do the same." Gender medicine is already being incorporated into many medical school courses.

RIGHT Dr Alyson McGregor, a gender medicine expert at Brown University, is pushing for changes in how men and women are treated



McGregor calls this “a new paradigm for the evolution of excellence in health care”. What she means is that gender medicine isn’t just about women. It’s about improving medicine for men as well. After all, trials that currently mix men and women are potentially making the results inaccurate for men too.

Collecting detailed information about both sexes is part of a larger process of transforming medicine, where advice is based not on the law of averages but on data for specific groups – whether they be male or female, black or white, young or old. Once the knowledge base builds and learning spreads, healthcare might look quite different.

McGregor’s junior doctors in emergency care are already taking a ‘gendered’ approach: the moment a patient walks in, they consider how their gender might affect the way a disease presents itself. Diagnostic tests are chosen according to the patient’s biological sex, and interpreted within a certain set of ranges for that sex. Treatment is prescribed according to sex-specific dosages.

The big step forward, says Kautzky-Willer, will be when pharmaceutical companies routinely take account of gender in their big trials of new drugs. “There will be costs, but it will only happen if the companies do it, because

“GENDER MEDICINE IS NOT FEMINIST, IT’S ABOUT REAL SCIENCE ... LATER THE PATIENT WILL REAP THE BENEFIT”

only they can afford to take on such large studies.” She says that the companies also need to continue safety studies until there are conclusive findings for both men and women. Currently, if drugs look safe on the basis of a male-dominated sample, the ‘trend’ is believed to hold for women as well as men, and the trial is ended.

But now more and more researchers – of both genders – are involved in gender medicine, she is hopeful that a corner has been turned.

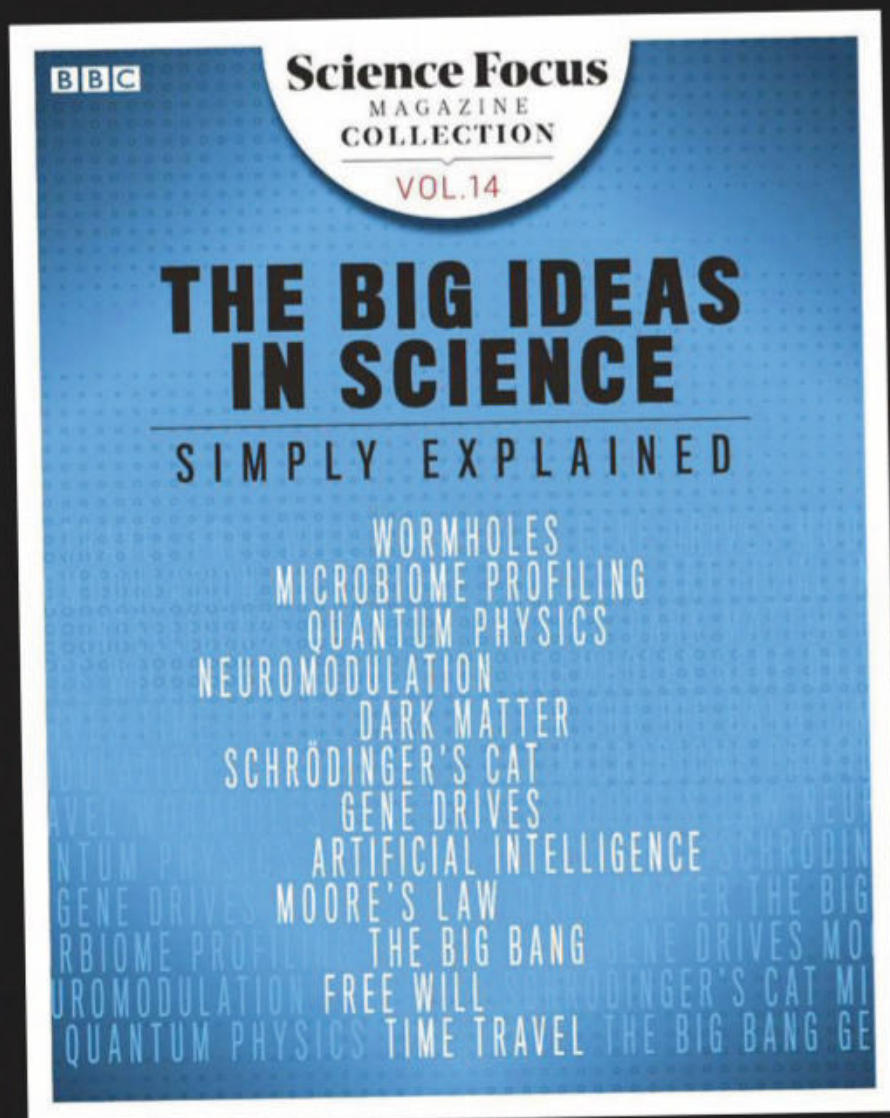
“It’s such a big field that everyone needs to be involved,” she says. “Gender medicine is not feminist, it’s about real science. We will get growing research and growing interest, and later the patient will reap the benefit.” The days of bikini medicine look numbered... **SF**

by **SIMON CROMPTON**

Simon is a science journalist and former medical editor on The Times.

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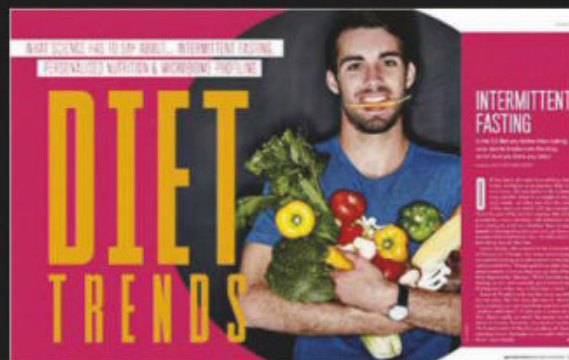
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RON BAKER

WHAT CAUSES GUSTS OF WIND?

Gusts are sudden but short-lived increases in the speed of the wind. They’re often created as wind brushes past buildings, trees or other obstacles, with the friction causing it to slow and then speed up again. Larger-scale variations in the direction or speed of wind (known as wind shear) can also create chaotic changes in atmospheric pressure, generating gusts as the air flows from high to lower pressure. Finally, as the Sun warms up a surface, the overlying air warms and rises, which also creates gusts as cooler, denser air rushes downward in its place. The higher the average wind speed, the gustier it is likely to be. This relationship depends on the local terrain, though: towns and cities generate more gusts through friction and solar heating. For the same average wind speed, urban areas are therefore likely to see much stronger gusts than open landscapes. *AFC*



ESTHER OWEN-WARD

ARE THERE TRACES OF MEDICINES IN DRINKING WATER?

Yes, and it's a growing cause for concern. In the early 2000s, a nationwide study by the US Geological Survey found that 80 per cent of streams in the US carried traces of pharmaceuticals, ranging from antibiotics and contraceptives to painkillers and antidepressants. These 'active pharmaceutical ingredients' (APIs) have since been found in the water supply of many countries, including the UK. Some get there simply by being excreted by patients; others after being flushed down toilets unused; others enter the water supply during the manufacturing process.

At first, the concentrations of the ingredients were thought to be too low to worry about. But studies have since found much higher concentrations in water supplies in cities around the world, raising the risk of effects on both aquatic life and humans. Antidepressants, for example,

have been found in the brains of fish downstream from sewage treatment plants, with some of these chemicals affecting their behaviour, making them less cautious. Researchers in the UK have also found fish with both male and female characteristics in almost 90 per cent of the river sites they've surveyed. The cause has been traced to compounds found in contraceptives. This discovery has, in turn, led to suspicions that similar contamination may be playing a role in the decades-long decline in human sperm counts that has been recorded by researchers in many countries.

Definitive proof of the effects of these APIs may never emerge: there are simply too many potential culprits and pathways via which they could cause harm.

While the concentrations are sometimes thousands of times lower than those in a single pill, the effect of low-level exposure over years or even decades is unknown. Given the potential risks, however, government agencies are already taking action. The European Commission is finalising a strategy for addressing the problem. Meanwhile, the US Food and Drug Administration has issued guidance to patients, warning of the need to dispose of unwanted drugs responsibly by following any instructions on the label, or by putting the drugs in the bin in a sealed bag. **RM**

501

The number of amphibian species around the world that have suffered from devastating losses due to the chytrid fungus.

MARK CHAPMAN

WHAT'S THE MOST ENVIRONMENTALLY FRIENDLY WAY TO TAKE SANDWICHES TO WORK?



We tend to assume that plastic is always the worst option for the environment. But when it comes to wrapping your sandwiches, aluminium foil – even though it's recyclable – is worse than cling film. Aluminium mining is energy-intensive and polluting: per square metre, aluminium foil contributes three times as much water pollution and six times as many greenhouse gas emissions. So unless you reuse the same foil six times, cling film is better. For an even better option, try a waxed cotton wrap, which can be reused for months. LV

EDWARD SEYMOUR, HOVE

ARE THERE ANY ARTIFICIAL SALT SUBSTITUTES?

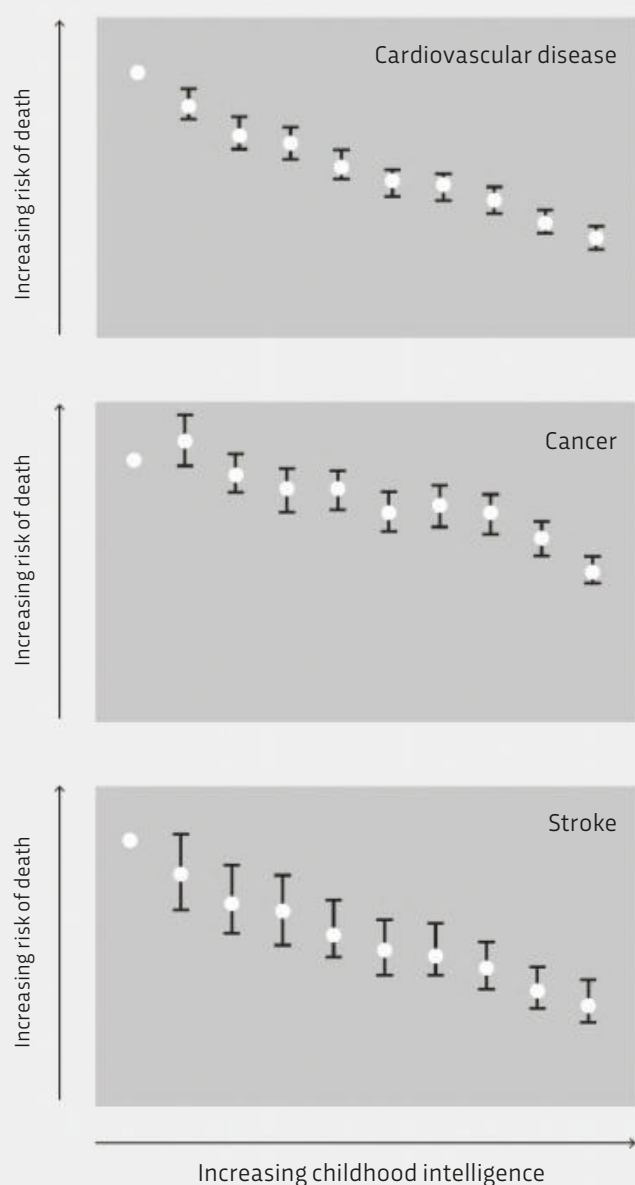
Table salt tends to be sodium chloride (NaCl) but salt substitutes contain potassium chloride (KCl), which has a similar taste. These are billed as lowering the risk of high blood pressure and heart disease associated with high sodium consumption. But potassium chloride is not without its downsides. It can interact with some prescription drugs and can be dangerous if you have kidney problems. **ED**

JAY HANCOCK, LEICESTER

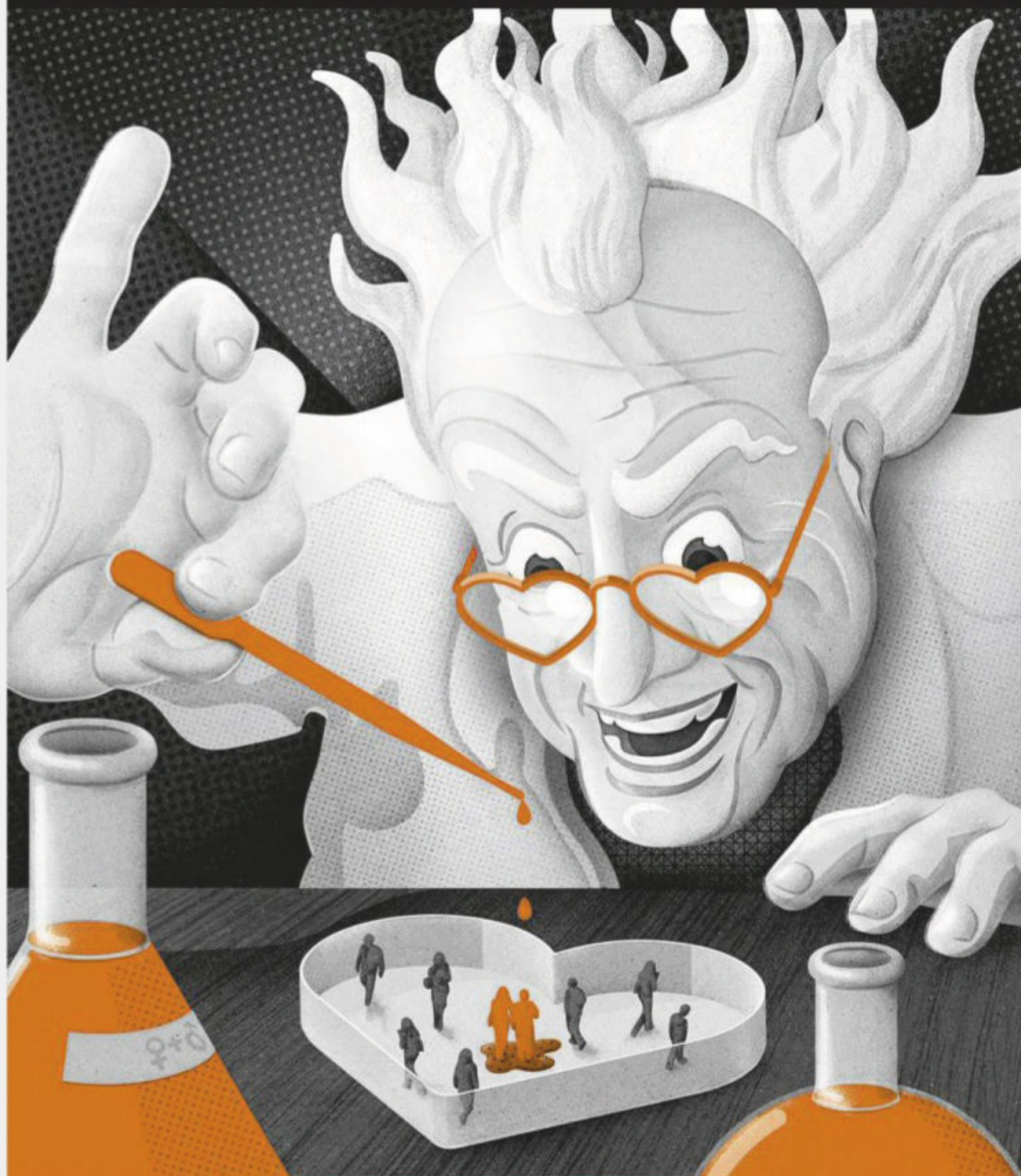
DO INTELLIGENT PEOPLE LIVE LONGER?

Anecdotally, smarter people do seem to live longer. Isaac Newton died in 1727 aged 84, the philosopher-mathematician Bertrand Russell lived to 97, while Nobel Prize-winning neurobiologist Rita Levi-Montalcini died in 2012 aged 103. And it's easy to concoct an explanation: smart people tend to be wealthier, so can afford better healthcare, and will probably have less physically demanding or dangerous jobs.

Yet studies suggest there may be a more subtle connection between longevity and intelligence (well, IQ scores, at least). In 2017, a team led by psychologist Prof Ian Deary at the University of Edinburgh published research covering over 65,000 people whose IQs were measured as children in 1947. It emerged that those who had a higher childhood IQ tended to have a lower risk of diseases like lung cancer, heart disease and stroke in adulthood – thus boosting their longevity (see graphs below). This may reflect better lifestyle choices, like healthier diets and lower rates of smoking. But the link also remained after accounting for those factors. This suggests that there may be some sort of genetic link between IQ and longevity, though exactly what this link is remains unclear. **RM**



EXISTENTIAL FEAR OF THE MONTH...



LOVE IS JUST A CHEMICAL REACTION

People who are in love have higher levels of several key hormones. For example, oxytocin and vasopressin – two hormones produced in a region of the brain called the hypothalamus – cause stronger feelings of attachment. The development of hormones that encourage us to form committed relationships makes sense from an evolutionary perspective: our ancestors would have been more likely to successfully raise, feed and protect their children if both parents worked together. But does this mean that love is just a chemical trick being played on our brains? Oxytocin has been shown to increase the amount of

time you spend gazing into the eyes of your loved one, and it also boosts your ability to read someone's emotions. Some perfume manufacturers have tried to exploit this by adding oxytocin to their scents, but the dosage is too low to have any effect. It's possible that a more thorough understanding of the way different hormones interact may eventually allow us to create a potion that increases our chances of falling in love. But things like shared history, values and cultural reference points also play a part in whether we fall in love, and these things aren't directly controlled by our hormones. **LV**



CHIARA KEMP (AGED 11), BELGIUM

WHAT'S A BANANA SKIN MADE OF, AND CAN YOU EAT IT?

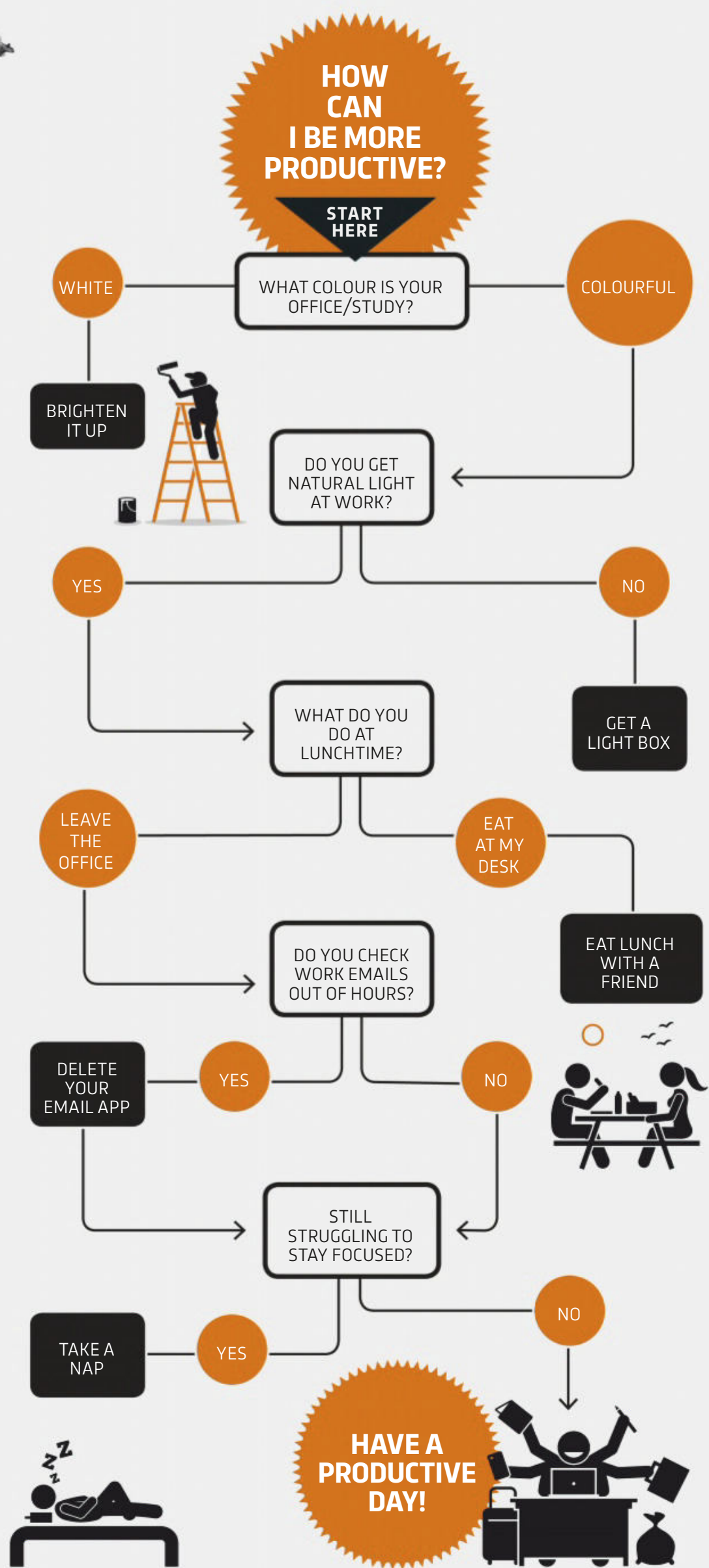
Banana peel is made of carbohydrates (roughly 60 per cent), fibre (30 per cent), water and small amounts of protein and fat. Banana skin's thickness and high fibre content make it quite tough and sometimes bitter, but it is edible and contains many minerals including potassium and manganese. Try adding one to a smoothie: take an unpeeled ripe banana, wash it, cut off the ends and slice. Add 200ml milk or yoghurt, a pinch of cinnamon, and blend. *AFC*

DAVID KELLY, MANCHESTER

WHAT HOLDS TOGETHER THE PROTONS AND NEUTRONS IN AN ATOM'S NUCLEUS?

All protons are positively charged, and as a result repel each other. So the fact that atoms even exist points to a force able to overcome this repulsion. Called the strong interaction, its origins lie in the particles lurking inside both protons and neutrons, called quarks. These possess a weird form of charge, whimsically termed 'colour', which glues them together inside their host particles – and also seeps out to bind the protons and neutrons together, too. *RM*

ALGORITHM YOUR LIFE



BRIGHTEN IT UP
In 2005, researchers at the University of Texas found that a white-painted office was less productive for clerical work than one with blue or aqua walls. A 2009 study at the University of British Columbia found that blue walls increased communication and creativity.

GET A LIGHT BOX
Natural light is important for regulating your sleep cycle. A 2013 study at Northwestern University in Chicago found that workers in offices with windows slept an average of 46 minutes longer per night than those in windowless offices. Artificial light boxes can help offset a gloomy office.

EAT LUNCH WITH A FRIEND
A 2011 study found that workers skipping their lunch break were less vigilant in afternoon tasks requiring memory and concentration. Communal breaks are even better. A study at Bank of America found that shared breaks led to a 15 to 20 per cent productivity boost.

DELETE YOUR EMAIL APP
Checking work email out of office hours erodes the boundary between work and leisure. A 2016 study found that those who were required to be available out-of-office had higher levels of the stress hormone cortisol. More stress means less sleep and worse performance.

TAKE A NAP
A coffee followed by a 20-minute nap is the best way to dispel drowsiness and restore productivity, according to a 2003 study at Hiroshima University. The nap recharges your brain, with the caffeine kicking in just as you're waking up.

NATURE'S WEIRDEST CREATURES...

THE ECHIDNA

If the concept of sin was invented for any creature, it was surely the echidna. For within the loins of this spiny little mammal – native to Australia and New Guinea – are hidden a multitude of deadly sins.

The first is lust. Every June to September, male echidnas trail after females in vast noisy groups like teenagers at a music festival. Their second sin is envy, because the echidna's sperm is capable of bunching together into rival-hating blobs 100-sperm strong, whose goal it is to block off other potential suitors in the female's reproductive tract. The third sin – sloth – applies only to the female echidna, as she is the only animal on Earth capable of being mated with while in the deep sleep of hibernation.

Thankfully, all four species of echidna score lower on the other sins. Unlike their wrathful cousin the platypus, they are not venomous, and they don't score well on gluttony or greed either, because – unlike most other mammals – they lack a true

stomach. And what about pride, the final sin? Let's just say that the male echidna is rather well-endowed, with a four-headed penis otherwise unseen in nature. Whether or not you consider this something to be proud of is your call. *JH*



ANDREW ROBERTSON

IS IT POSSIBLE TO FLY AROUND THE EQUATOR NON-STOP AND STAY IN DAYLIGHT?

Yes – but only in theory. The Earth is roughly 40,000km in circumference at the equator, and completes one rotation every 24 hours. This means that the Sun effectively zooms across the face of the Earth at the equator at around 1,700km/h. So you'd have to travel at least this fast to stay in daylight. But that's around 1.5 times the speed of sound – and twice as fast as a conventional passenger plane. In theory, a supersonic jet could manage it, but even then in-flight refuelling and speed restrictions over land would reduce the effective speed well below what's needed. Not even Concorde managed it. In October 1992, it achieved its fastest-ever circumnavigation of the Earth, and it still took more than 33 hours. *RM*



SUNDUS ILOTT

WHY DO PEOPLE SCRATCH THEIR HEADS WHEN CONFUSED?



Head-scratching is an example of what biologists call a 'displacement activity', where an animal that's unable to choose between two conflicting options will opt for neither and instead perform some unrelated behaviour. For example, a bird that's unsure whether to attack or flee from a rival might suddenly begin to

peck at the ground. Originally, these behaviours – which can also include preening and grooming – may have emerged because the soothing physical contact, or the familiarity of a routine behaviour, acts to calm a stressed animal.

But the behaviours have evolved into part of the non-verbal language that animals use to signal their emotional state. A 2017 study at Portsmouth University found that macaques scratch their heads when stressed, and this acts as a signal that makes other macaques less likely to attack or harass them. So we may have inherited this social cue from our ancestors, perhaps as a way of warning people to leave us alone when we're thinking hard. **LV**

SARAH GORDON, COVENTRY

WHY DO WE SHAKE WHEN WE'RE NERVOUS OR FRIGHTENED?

When we're anxious, a region of the brain called the amygdala responds to the threat by increasing the production of adrenaline, the 'fight-or-flight' hormone. Adrenaline works directly on receptor cells in muscles to speed up the contraction rate of the fibres, ready for fighting or fleeing. High levels of adrenaline can therefore lead to muscles twitching uncontrollably, making us shake. Deep, 'box' breathing (in for a count of 4, hold for 4, out for 4) can help to calm us down again. **HG**



PATRICK ROSE, VIA EMAIL

WHAT'S THE LONGEST TIME THAT SOMEBODY HAS BEEN CONSTIPATED?

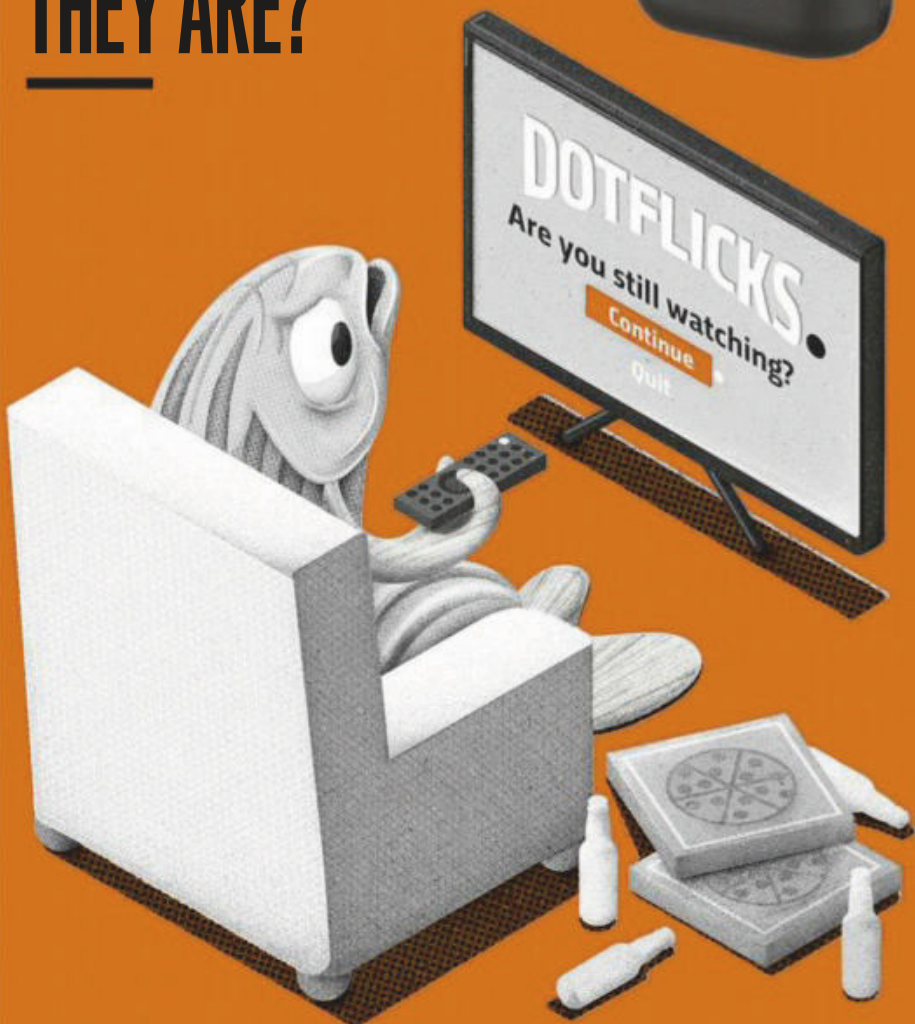
In 2013, a 28-year-old woman from Chembur, India, had to have surgery to remove a "football-sized faecal mass" after 45 days without a bowel movement. It's not known what caused it, but other cases of extreme constipation have been linked to spinal cord damage or rare medical conditions, which affect the nerves controlling the muscles of the intestine. Sufferers cannot poo normally and must rely on enemas and laxatives. **LV**

GETTY IMAGES X4, NASA ILLUSTRATIONS: DAN BRIGHT

QUESTION OF THE MONTH

KATE HARRIS, TORQUAY, DEVON

HOW DO FISH KNOW WHO THEY ARE?



WINNER

Kate wins a pair of JBuds Air earbuds. JBuds Air offer crystal clear sound and a four-hour Bluetooth battery life, plus 10 hours with the included 500mAh charging case. They have three sound settings to suit all music tastes, while their IP55 sweat resistance makes them perfect for a workout. jlabaudio.com

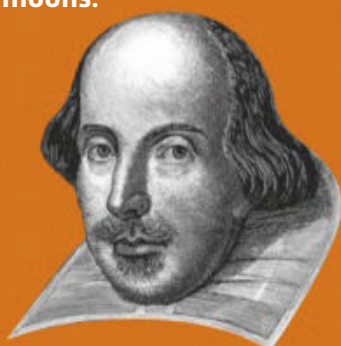
Fish can't see themselves, and so presumably don't know what they look like. But they're still able to recognise other members of their own species and join them in a shoal. Smell is an important sense for fish. Many species release potent pheromones, which tell other fish not only if they belong to the same species but also if they're siblings. Recent studies of zebrafish, the lab rats of the fish world, have also shown that some fish may spot their own species by the way they move. When a zebrafish is shown a computer screen with a black dot moving in bursts, characteristic of a zebrafish's swimming style, it will follow the dot for hours. Even fish brought up in isolation will trail after the dot, suggesting that this behaviour is innate in zebrafish, and possibly in other species too. **HS**

WHAT CONNECTS

URANUS AND IMELDA STAUNTON?



Uranus is the seventh planet from the Sun, and was the first to be discovered with the aid of a telescope. It has 27 known moons.

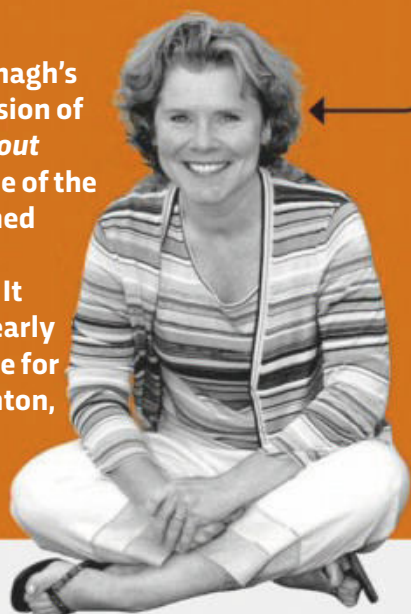


Unlike those of every other planet, the moons of Uranus are not named after gods from ancient mythologies, but after characters from the works of William Shakespeare and Alexander Pope.



Initially, the names of the outermost moons all came from *The Tempest*. That trend ended in 2003 when a newly discovered moon was named after Margaret, a chambermaid in *Much Ado About Nothing*.

Kenneth Branagh's 1993 film version of *Much Ado About Nothing* is one of the most acclaimed Shakespeare adaptations. It featured an early cinematic role for Imelda Staunton, who played Margaret.



MILLIE WILLIAMSON, VIA EMAIL

Why are certain fragrances considered masculine or feminine?

It's largely down to the gender associations we learn through our culture and our memories – such as the scents we remember our parents or our first loves wearing. Certainly, the perfume industry follows cultural convention by labelling floral, fruity smells as being for women, and muskier, spicier smells for men. But where do these associations come from in the first place? For the 'feminine' smells, one possibility is that it has to do with flowers being used as metaphors of feminine fertility since antiquity, while the link between men and musky smells may come from the fact that men's body odour is usually more musky than women's.

However, the 'gender identity' of a smell is often not that obvious. One small study at Stockholm University involved volunteers smelling various commercial scents in a plain bottle and rating them for masculinity or femininity. With the exception of the most floral and spicy scents, their ratings showed little correspondence with the commercial gender categorisations. *CJ*



SARAH LAMBERT

WHY DO MEN GO BALD FROM THE TOP OF THEIR HEADS?

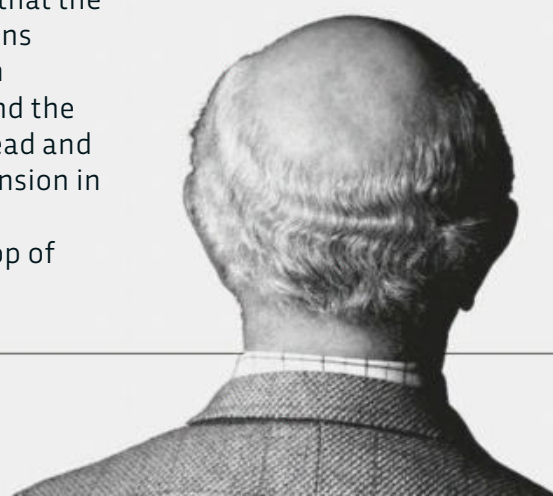
Characterised by hair loss from the top and front of the head, 'male-pattern hair loss' is partly determined by genetics and partly by high levels of a male sex hormone called dihydrotestosterone (DHT).

The most recent hypothesis suggests that the hair loss process begins during puberty, when growth of the skull and the muscles in the forehead and neck increases the tension in a tight band of tissue stretching over the top of

the head. The more DHT there is, the more these muscles contract, which causes inflammation and brings in more DHT. Over time, the DHT thickens the band of tissue, restricting the supply of blood and nutrients to the hair follicles

above it. The follicles on top of the head get smaller and eventually disappear, while those on the sides of the head remain largely unaffected.

However, this theory is still a work in progress. Some experts believe that DHT impacts the hair follicles directly. And DHT itself remains something of a mystery, being responsible for hair growth – not loss – on the face and in the armpits and pubic areas. **HG**





DEAR DOCTOR...

DELICATE ISSUES DEALT WITH
BY *SCIENCE FOCUS* EXPERTS

I THINK I'M TURNING INTO MY MOTHER. HELP!

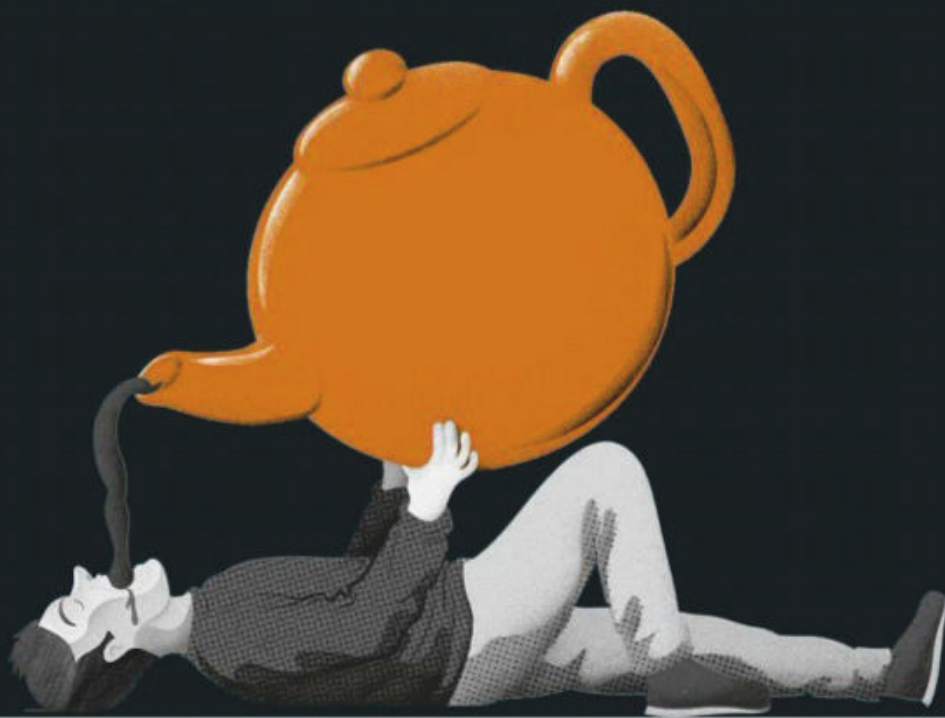
As we get older, our personalities tend to mature in a typical fashion – we become more emotionally stable, but also more closed-minded. So the discomfiting sense that you're turning into your mum may be because your personality is becoming more like hers was when you established your formative memories of her. Of course, it's worth remembering that, assuming you were not adopted (or born via a surrogate or egg donor), then you will share half your mother's DNA, on average. So as much as you may have tried to rebel in adolescence, it's not that surprising that your similarity to her is beginning to shine through (about half the variation in personality from one person to another is down to genetic differences). However, research from California compared the average personality profiles of two different generations – women born in the 1920s and in the 1950s. It found that, on average, women are becoming more confident and ambitious. So while you may be turning into your mum in some respects, it's likely you are a more outgoing, self-assured 21st Century version. *CJ*



I'M ADDICTED TO TEA. IS IT POSSIBLE TO DRINK TOO MUCH OF IT?

Tea contains natural antioxidants called polyphenols, which have many positive effects on the body. For instance, drinking more than three cups a day has been found to reduce the risk of a heart attack. The 40mg of caffeine per cup (roughly half as much as coffee) won't have any impact on your health until you get to

at least eight cups per day – so you should probably stop at that point. But it's possible to take anything to extremes. In 2013, a US woman lost all her teeth due to fluoride poisoning from tea. She was drinking a pitcher of iced tea every day for 17 years, and each pitcher was reportedly brewed with 100 to 150 tea bags! *LV*



HOW CAN I STOP MY HEADPHONES TANGLING THEMSELVES INTO THE KNOT FROM HELL?

People were wrestling with this one long before headphones were even invented. In 1889, the comic writer Jerome K Jerome noted in *Three Men In A Boat* how rope can become tangled seemingly by itself. Surprisingly, the explanation was only

discovered by mathematicians in 1988. Put simply, it turns out that, unless handled carefully, the chances of the free ends of stringy objects – such as headphone wires – going through the motions needed to make a knot increase

rapidly with the length of the string or wire. Happily, that leads to a simple way to cut the risk of tangles: get rid of the troublesome free ends by clipping the earbuds and the jack together to form a loop – using, say, a plastic hairgrip. *RM*

SAM FOX, ABERDEEN

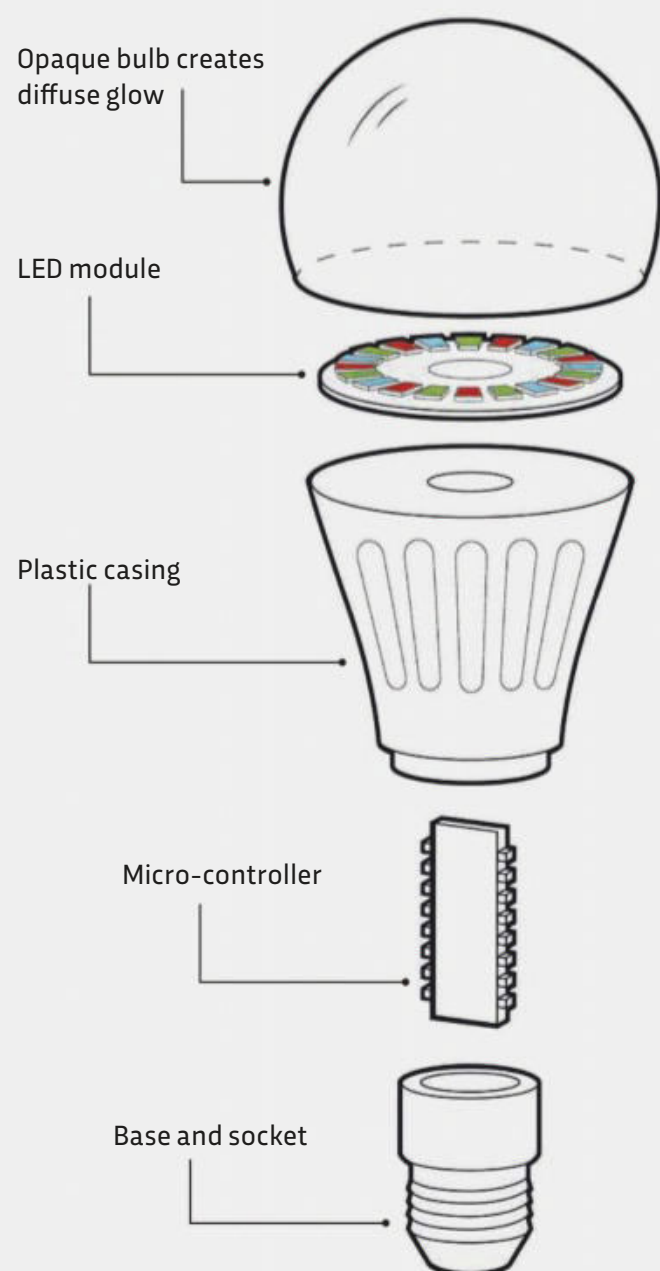
AFTER DRINKING ALCOHOL, WHY DO SOME PEOPLE GET AGGRESSIVE?

Alcohol alters activity in the frontmost part of the brain (the prefrontal cortex), which is involved in decision-making and self-control, and this makes drinkers more impulsive. This can manifest in relatively innocuous ways – such as being more inclined to tell jokes to a stranger – or in more dangerous ways, such as driving fast or reacting to provocation. The disinhibiting effect of alcohol exaggerates the drinker's sober personality. So people who are more inclined to anger, and less concerned about future consequences, are more likely to get aggressive when drunk. *CJ*



DAVID CONNOLLY

HOW DO COLOUR-CHANGING LIGHT BULBS WORK?



Colour-changing light bulbs use red, green and blue LEDs to create their range of colours, switching them on in different combinations using a tiny computer ('microcontroller'). Red, green and blue LEDs are used because our eyes have colour-sensitive cells called cones that are roughly attuned to these three wavelengths of light, and we see colours as different combinations of these wavelengths. If you want yellow, the bulb turns on red and green. For cyan, it turns on green and blue. For white, it turns them all on. To fine-tune the shades of colour, the bulb also pulses the LEDs very quickly – if it pulses blue so that it's on only 50 per cent of the time, for example, we see a darker blue. With these tricks, colour-changing bulbs can create millions of subtly different colours. **PB**

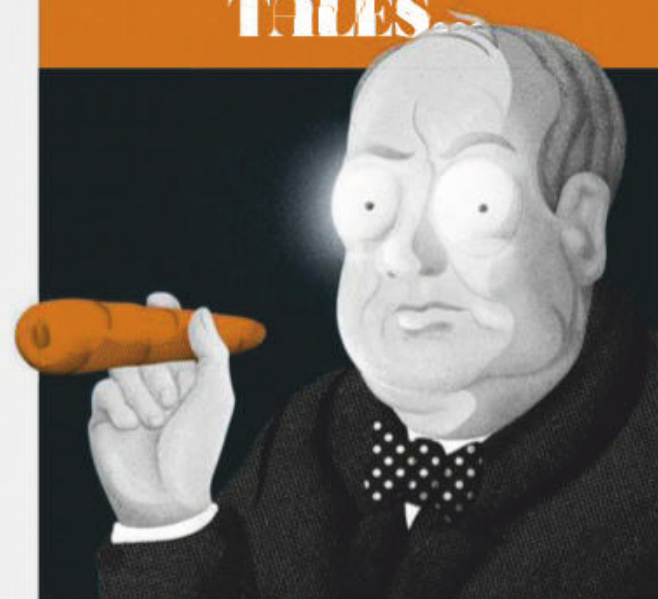
JACOB PINNOCK

WHY ARE HUMANS SO CURIOUS?

To the human brain, new information is like delicious food. A recent study at the University of Reading found that participants' curiosity to find out how a magic trick worked triggered activity in the same area of their brains as a hunger for food. Those who were most curious were even prepared to risk a (mild) electric shock for the chance to have the magic explained. Humans, it seems, are hardwired to be curious, and this instinct would have been a potential lifesaver for our ancestors – the person who dared to poke their head around the corner may have found new food or water, or spotted a predator approaching. **CJ**



OLD WIVES' TALES



CARROTS HELP YOU SEE IN THE DARK

Carrots won't give you pure night vision, but eating them will certainly help to keep your eyes healthy.

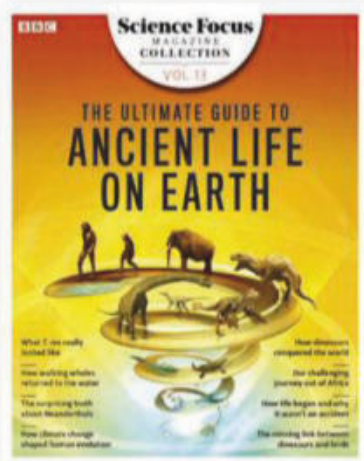
The idea that carrots help you see in the dark partly has its roots in WWII propaganda. British airmen had a fearsome reputation for their ability to shoot down enemy bombers during night-time London raids. The secret lay in new radar technology, but the British put out a rumour that the airmen were avidly devouring carrots to boost night vision. It's not clear whether the German army fell for the ruse, but the British public certainly did, helped by government adverts proclaiming: 'Carrots keep you healthy and help you to see in the blackout'.

Carrots are rich in an orange pigment called beta-carotene. Enzymes in the body convert beta-carotene into a form of vitamin A known as retinol, which is vital for eye health.

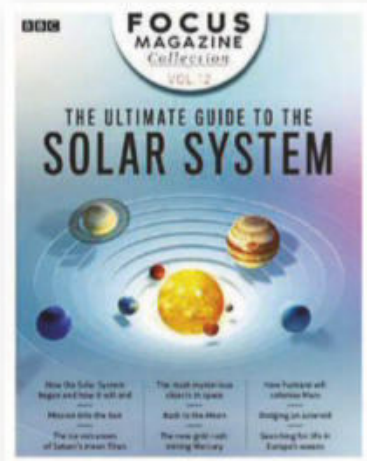
Other enzymes convert retinol into a chemical called retinal, which is important for forming a pigment called rhodopsin that operates in low-light conditions. Rhodopsin is found in photoreceptor cells known as rods which reside at the back of the eye, in the retina. These cells are responsible for our vision in low-light, and eating carrots will help to keep them in tip-top condition. Without any vitamin A, we would develop night blindness. **ED**

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MAGAZINE

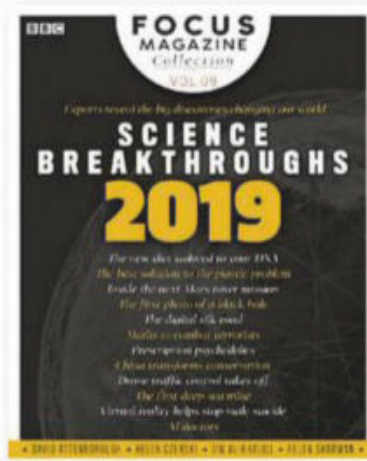
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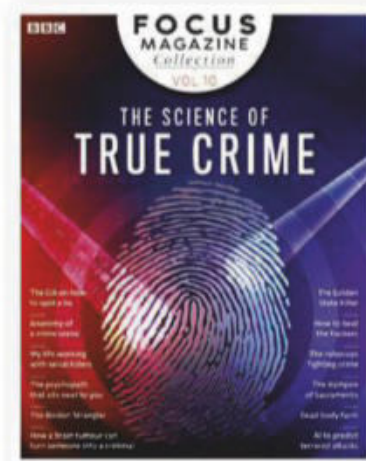
The story of life on Earth: how it began, how dinosaurs conquered the world, what the first mammals looked like, and how humans spread across the planet.



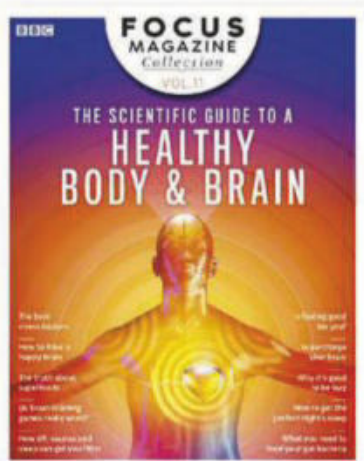
Discover how the Solar System formed and how it will die. Find out about cutting-edge missions to other worlds. Learn about plans to colonise the Moon and Mars.



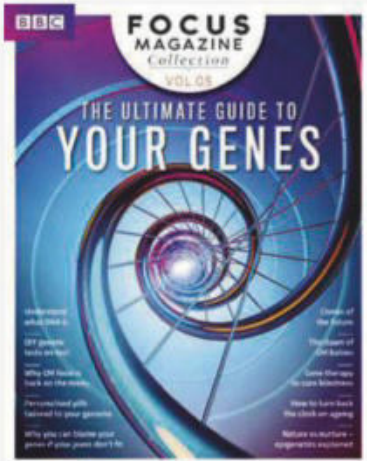
Experts reveal the key breakthroughs this year: DNA diet, cancer vaccine, exoplanets, legal highs, 5G, drone deliveries, deep-sea mining, artificial intelligence.



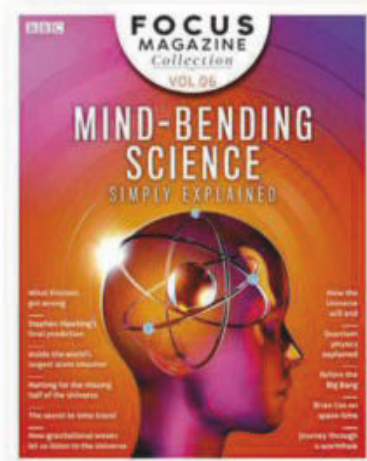
Discover how forensic scientists investigate crime scenes, get CIA secrets on how to extract the truth, and go inside the minds of psychopaths and serial killers.



Discover what science shows are the best ways to keep your brain sharp and your waistline slim, while staying fit, healthy and happy.



Each life form on this planet has a unique genetic code – DNA. Now geneticists are using DNA to improve our health, eliminate hunger and even bring back animals...



Quantum physics, space-time, black holes, multiverses... The nature of the Universe can make your head spin. But this special edition can help make things easier.



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RADAR

WHAT'S LIGHTING UP OUR ANTENNA THIS MONTH



1. Examine genius

Einstein's 100-year-old theory of gravity has paradoxes that leading scientists still can't move past. *Chasing Einstein* investigates whether it will stand the test of time.

Chasing Einstein
UK premier 19 May
sci-fi-london.com

2. Debates and discos

Flock to Hay-on-Wye for this festival of debates, comedy and music. This year, you'll hear from ex-Tory MP Anna Soubry, comedian Helen Lederer and physicist Roger Penrose, among others.

HowTheLightGetsIn
24-27 May
howthelightgetsin.org

3. Admit uncertainty

We constantly hunt for patterns in disorder, unwilling to accept that we'll always be hampered by randomness. Michael Blastland explains why it's better to give in to the limits of our knowledge.

The Hidden Half
£14.99, Atlantic Books

4. Explore the mind

In his youth, *Homeland's* David Harewood was in secure psychiatric ward. In this poignant show, he revisits his past and talks to young patients with psychosis.

Psychosis With David Harewood
Coming soon to BBC One

5. Robo rock

In a festival-style exhibition at the Barbican, you can experience AI's full capabilities with projects from DeepMind and MIT, and interact directly with exhibits and installations.

AI: More Than Human
16 May-26 August
barbican.org.uk

6. Immerse yourself

Oculus's new wired VR headset has a better display and optics than the original Rift. A new feature called Passthrough+ allows users to see the space around them without taking the headset off.

Oculus Rift S
From £399, oculus.com

BBC, FLPA, GETTY IMAGES

Shift work has been linked to shortening lifespans by up to 10 years p95



15-17°C

The optimum temperature your bedroom should be at for the soundest sleep p95



Profile

A CRISIS OF KNOWLEDGE

MICHAEL BLASTLAND'S NEW BOOK, *THE HIDDEN HALF*, LOOKS AT HOW OUR URGE TO CONSTANTLY FIND ORDER AFFECTS SCIENCE, POLITICS, BUSINESS AND ECONOMICS, WITH SOMETIMES CATASTROPHIC RESULTS...



WHAT'S *THE HIDDEN HALF* ALL ABOUT?

It's a book of mysteries and errors that reflect the fact that our knowledge is much weaker and less reliable than we think it is. I've tried to tell some of the stories which, instead of revealing secure robust knowledge of causal influences, actually show us that we don't – and possibly never will – have secure knowledge of some of the causal processes in our lives.

THAT'S AN UNCOMFORTABLE THOUGHT...

I think we exaggerate our distaste for uncertainty. Do you want to know all your Christmas presents for the rest of your life? Do you want to know the time and date and manner of your death? There are clearly some instances in which uncertainty is actually a good thing. The question is, can we talk about uncertainty in ways that people find acceptable for the tricky questions about what's going on in the world? Because people fear that if they admit uncertainty they'll lose their authority. If you say, "I'm not sure," then people say, "Oh, I'm not going to listen to you then."

There's research being done by the Winton Centre for Risk and Evidence Communication. They tell you in

“The scientific method is the best way of making progress, but acknowledging our limitations is an important part of making that progress”

different ways how many tigers there are in the world. Then they ask you if you trust the information, and whether you trust the person telling you – two separate questions.

They say, “There are X thousand tigers. What do you say to that, and do you trust me?” Then they say, “We think there are X thousand tigers, but we're not quite sure. Now how well do you trust the information and how well do you trust me?” And the third one: “We think there are X thousand tigers, but we're pretty confident that the answer is within a thousand more or a thousand fewer.” The last of those achieves the highest level of trust. People lose confidence in the number a bit, which they should,



THE HIDDEN HALF
BY MICHAEL BLASTLAND
(£14.99, ATLANTIC BOOKS)



FAR LEFT:
Researchers have
used estimates of
tiger numbers to
demonstrate how
much we trust
experts and the
information
we're given

LEFT: Michael
Blastland, author of
The Hidden Half

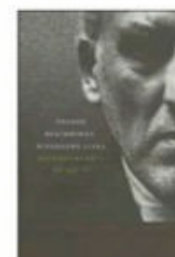
Author's bookshelf



EPIDEMIOLOGY, EPIGENETICS AND THE 'GLOOMY PROSPECT'

GEORGE DAVEY SMITH

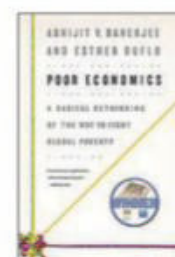
George's brilliant, eclectic discussion of randomness in human development, which vividly reifies chance with human stories, was the initial spark for the thoughts that led to my book.



SHARED BEGINNINGS, DIVERGENT LIVES, DELINQUENT BOYS TO AGE 70

JOHN LAUB AND ROBERT SAMPSON
(£27.95, HARVARD UNIVERSITY PRESS)

A wonderful analysis of the surprising randomness in criminal life courses. It shows how benign uncertainty can be.



POOR ECONOMICS

ABHIJIT BANERJEE AND
ESTHER DUFLO
(OUT OF PRINT)

An invigorating challenge to thinking about problem-solving in developing countries, from the bottom up, acutely conscious of the power of detail – a recurrent theme in *The Hidden Half*.

because we're not that sure about the number. But they gain confidence in the person giving them the information. So the old belief that you lose authority if you admit to uncertainty doesn't hold up. We can present information in ways that admit real, unavoidable uncertainty and gain credibility.

SURELY THE PUBLIC IS SOMEWHAT AWARE THAT WE CAN'T ALWAYS BE COMPLETELY PRECISE?

The classic one right now is George Osborne telling us that Brexit will cost every family in the UK £4,500. Not £5,000, not a few thousand, but £4,500. We have a lot of people telling us things, claiming that they have the authority to give these verdicts, and I often suspect that they just can't know with anything like that sort of precision. Admitting that would do us a lot of good, and it would enhance people's credibility.

THIS IS GOOD TIMING FOR A BOOK ABOUT ADMITTING TO WHAT WE DON'T KNOW.

Yes, we've had a couple of shocks recently to our self confidence in our ability to understand what's going on in the world. As an example, we had a recession in 2008, the consequences of which are still being felt. Hardly anybody saw that coming with the ferocity it actually delivered. Economists believed they had a reasonably robust understanding of the way the economy should have

behaved in those periods, and it failed. On reflection, we decided we didn't really understand the way the banking sector worked within the economy.

So we're not always right about the economy or public policy. But even science is going through a replication crisis, where many experiments are being repeated and giving inconsistent results. Given all of this, how should we view science, which is usually held up as our most reliable source of information?

[Science] is the most reliable source of information that we have, but it's still unreliable. The scientific method is absolutely the best way of making progress, but acknowledging our limitations is an important part of making that progress. Fooling ourselves about the degree of our understanding means we'll fail to correct our misunderstandings. It's integral to the scientific method that we acknowledge the exceptions, the difficulties, the awkwardness, the weakness.

WHAT PRACTICAL TIPS SHOULD WE TAKE FROM THE BOOK?

You can still make any decision you like; uncertainty does not mean that you become paralysed. You just have to acknowledge the uncertainties, because that might change the kind of decision that you make. We might create a Plan B, or say we're not going to bet the ranch on this one, we're going to bet modestly. You can recognise that your policy that has been demonstrated in a few schools in the West Midlands may not translate to many other schools if the sample isn't big enough, or if the protocol hasn't been adhered to properly. Don't expect things to generalise with perfection if you're a decision maker. There are things we don't know, but we'd do things a lot better if we were frank about our limitations.

MICHAEL BLASTLAND

Michael is a journalist and broadcaster. He makes programmes for BBC Radio 4, like *More Or Less* and *Analysis*. **Interviewed by BBC Science Focus editorial assistant Helen Glenny.**

RECOMMENDED

FIND OUT WHAT'S CAUGHT OUR ATTENTION THIS MONTH



WHAT I'M READING

Helen Glenny
EDITORIAL ASSISTANT



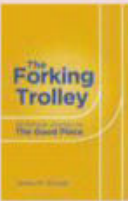
THE KNIFE'S EDGE
PROF STEPHEN WESTABY
(£20, WEIDENFELD & NICOLSON)

The 'doctor recounting case studies' genre now sees scores of similar, somewhat-interesting tomes floundering in the shadows of masterpieces like Paul Kalanithi's *When Breath Becomes Air*, or Adam Kay's *This Is Going To Hurt*. But *The Knife's Edge* by retired cardiac surgeon Stephen Westaby offers something different. He carries the typical self-important bravado of many a surgeon-turned-writer, but his is down to a head injury sustained during his university years. This injury affected his critical reasoning and risk-avoidance, leaving him uninhibited, irritable and reckless. This is a man given the nickname 'Jaws', because of the speed at which he could amputate a limb. That said, *The Knife's Edge* is peppered with stories of extraordinary compassion and awareness. He recognises the damage caused to his family by his choice of career and his dedication to it, and the book reads as though compassion and empathy can be partially won back through years spent among the sick, the scared and the grieving. The book is also home to Westaby's thought-provoking (if not entirely convincing) critique of the operation of the NHS, based on his experience as both an employee and as a family member of a patient. It's an interesting jaunt through a career spent in an operating theatre, best read when you're in a resilient frame of mind.



WHAT I'M READING

Sara Rigby
ONLINE ASSISTANT



THE FORKING TROLLEY: AN ETHICAL JOURNEY TO THE GOOD PLACE
BY JAMES RUSSELL
(£8.99, PALAZZO)

Am I a good person? When it comes down to it, what does it mean for an action to be good? Does it depend on my intentions or on the outcome? Does the end justify the means? Moral philosophy is a complicated topic, full of difficult questions and intimidating words like 'deontological' and 'consequentialist'. But trying to be good doesn't have to be confusing: in *The Forking Trolley*, James Russell takes us through the basic concepts, ideas and theories of ethics. Russell teaches philosophy through examples from the morality-themed sitcom *The Good Place*. In the popular US show, Eleanor Shellstrop dies and wakes up in The Good Place (the analogue for heaven that gives the show its title) as a reward for the life she lived on Earth. But the self-described 'Arizona trashbag' soon realises that she's there by mistake. She takes on the task of trying to be a better person to earn her place there, with the help of moral philosophy professor and fellow resident Chidi Anagonye. In this book, Russell draws on her experiences to delve deeper into the moral questions she face. Don't go to it looking for answers, because you'll be disappointed. There are no simple solutions when it comes to ethics. What this book does give you is questions, and a guide to find your own answers.



WHAT I'M WATCHING

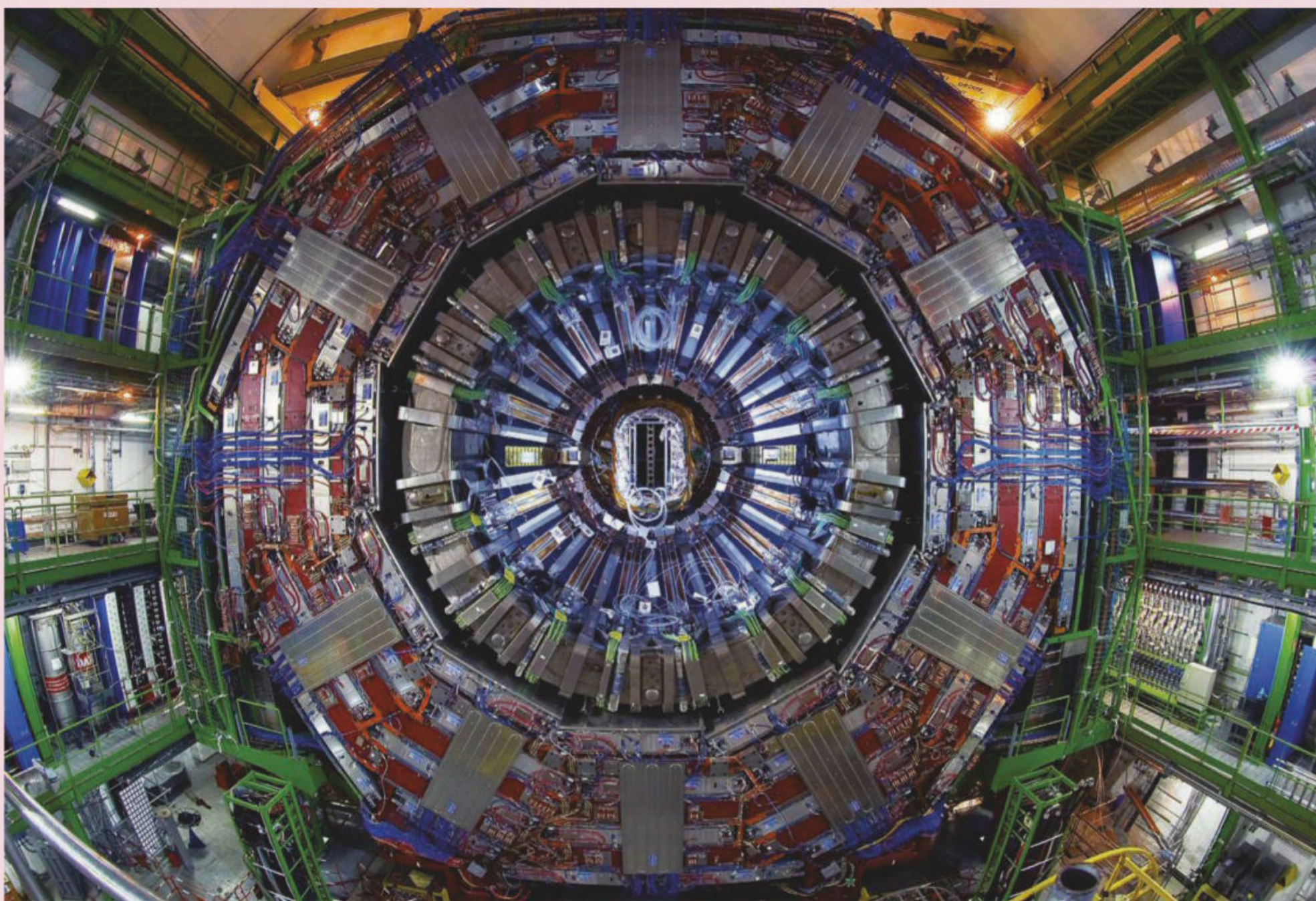
Jason Goodyer
COMMISSIONING EDITOR



PSYCHOSIS WITH DAVID HAREWOOD
BBC TWO,
COMING SOON

One morning when he was in his early-20s, *Homeland* actor David Harewood woke up to find himself locked into a secure psychiatric ward in North London's Whittington Hospital. He had no idea why he was there or how he had got there. He was in the midst of a severe psychotic episode that had left him plagued by delusional beliefs, tormented by imaginary voices in his head, and experiencing great chunks of lost time in which he would have absolutely no idea of what he had been doing. He would later make a full recovery and go on to have a successful acting career on both stage and TV. But now 30 years on, and left with only patchy memories of what happened, he's finally found himself ready to revisit the past. Throughout his journey, he pores over medical notes taken by the consultants who were treating him at the time. He seems faintly amused when





he finds that he would often claim to have fantastical abilities such as being able to travel to the Garden of Eden or pluck musical instruments out of thin air. But he also learns that his behaviour was often severely distressing for those around him – at one point he became so agitated that it took six police officers to restrain him.

Though not commonly talked about, it is currently estimated that around 1 in 100 people in the UK will be affected by psychosis at some point in their life with figures rising dramatically over recent years. As an aside to his own story Harewood visits a drop-in centre for young people who are currently recovering from, or still dealing with, severe bouts of psychosis. Their stories are genuinely upsetting and Harewood's sensitive and candid approach to speaking to them leads to some of the most poignant scenes in the film.



WHAT I'M WATCHING

James Lloyd
STAFF WRITER

CHASING EINSTEIN

UK PREMIERE 19 MAY
SCI-FI-LONDON FILM FESTIVAL

How do you search for a needle in a haystack when you don't even know what the needle looks like? That's the conundrum facing scientists who are searching for dark matter – the mysterious entity that's thought to make up around 85 per cent of the matter in our Universe.

This compelling new documentary follows some of these scientists, who are chasing the vision of gravity that was laid down by Einstein more than 100 years ago. If the Universe behaves in the ways that Einstein's General Theory of Relativity says it should,

then dark matter – and its gravitational pull – is needed to account for certain observations, such as the behaviour of galaxies.

But with no one having yet glimpsed dark matter, could Einstein's theory be ready for an update? That's the premise of *Chasing Einstein*. We meet the physicists who are racing to make the first detection at experiments such as XENON and CERN's ATLAS. There's a poetry in the contrast between these gigantic machines and the cosmic whispers that they're looking for. Meanwhile, other scientists in the film are questioning whether dark matter exists at all, which raises an uncomfortable possibility for the dark matter hunters: could they be seeking something that's ultimately just a figment of their imagination?

It's this human side to the story that makes for the most absorbing viewing, and I would've loved the documentary to have delved even further into the scientists' hopes and fears.

Large-scale experiments like the ATLAS detector are searching for dark matter, but results are yet to be forthcoming

Engineer your sleep

BOOST YOUR 40 WINKS TONIGHT WITH THESE SLEEP-PROMOTING GADGETS



DREEM HEADBAND

The Dreem Headband employs the techniques that Dr Penny Lewis (see right) is studying in her lab. It tracks brain activity, heart rate, movement and breathing to identify sleep stages in real time, and plays sounds to improve your sleep. Lewis warns that this method is still being refined, but is excited that products like this allow users to have a go at home.

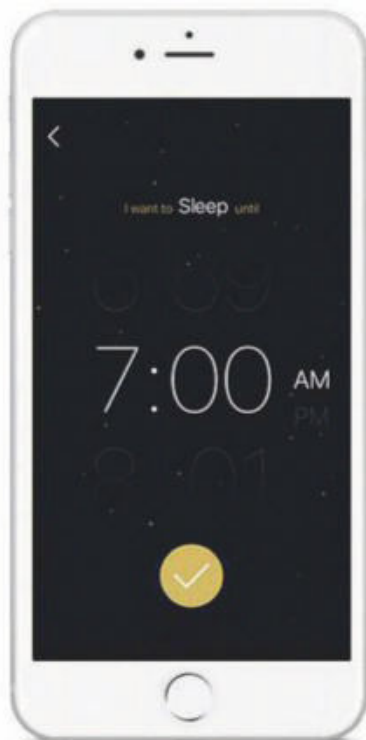
€499 (£425 APPROX)
DREEM.COM



ANY EYE MASK

If you're one of those sleepers who's woken up easily by light, this low-tech solution could hugely improve your sleep, especially as the mornings get lighter.

FROM 49p, VARIOUS RETAILERS



PZIZZ

Pzizz is an app that plays soundtracks to help you sleep, layered with voice narrations that are based on clinical sleep techniques, like breathing exercises and guided meditations. Like most sleep interventions, this won't work for everyone, but it works well for some.

FREE, WITH IN-APP PURCHASES
PZIZZ.COM



FITBIT CHARGE 2

Though you can only track sleep cycles with precision using EEG, these trackers, which use movement and heart rate to provide sleep data, make a reasonable guess. This information helps some people create healthy sleep habits. For others, it's just something extra to worry about.

£139.99, FITBIT.COM



SOUND+SLEEP MINI

This portable sleep sound machine plays white, brown or pink noise – depending on your preference – to drown out noises that might otherwise wake you.

£67.95, SOUNDOFSLEEP.COM

Troubleshoot

SLEEP SCIENTIFICALLY



DR PENNY LEWIS ENGINEERS SLEEP TO IMPROVE MEMORY AND BRAIN FUNCTION. BUT TO REALLY HELP YOUR BRAIN, SHE SAYS YOU NEED TO START WITH THE BASICS

WHY IS SLEEP IMPORTANT?

Sleep regulates the immune system, it's involved in regulating our body temperature, and it has huge impacts on the brain. We see direct correlations between the breakdown of sleep as people age and atrophy of different parts of the brain, as well as shrinkage and cell death, and we think that is associated with descent into dementia and even Alzheimer's disease.

Recent research has shown that sleep is really important for flushing toxins out of the brain. One of those [toxins] is beta amyloid, which is deposited in the brain over time, and can build up and form the plaques that are associated with Alzheimer's disease. Sleep has been shown to facilitate that flushing by up to 80 per cent compared to a waking state. And that's just an example of one toxin, and it's likely that sleep is involved in flushing many out.

When you're involved in shift work, you're sleeping in irregular patterns, so you see increasing instances of things like heart disease and breast cancer. [Shift work has] been linked to shortening the duration of people's lives by up to 10 years. That's not even necessarily shorter sleep, but sleep at the wrong times.

WHAT SHOULD WE DO TO GET A GOOD NIGHT'S SLEEP?

Sleep hygiene is the number one thing that everyone can do to enhance their sleep. Keep a

regular schedule: go to bed at roughly the same time every night and wake up at the same time every morning. Make sure you have a place to sleep that's dark, quiet and comfortable. I would recommend blackout blinds and wearing an eye mask. Your sensitivity to light is genetic, so some people's sleep is not disrupted by light at all, but a high proportion of people actually find when they try blackout blinds or an eye mask that it enhances their sleep dramatically.

The optimal room temperature for sleep is 15°C to 17°C. If possible, open a window to let some fresh air in. Knock off the caffeine at least seven hours before you go to bed, and don't have huge amounts of sugar before bed either. These are the things that make more difference than anything else.

IS THERE AN OPTIMAL TIME TO SLEEP?

You might have heard about larks and owls: these are actual genotypes. Larks are homozygous for a gene that biases them towards wanting to get up really early in the morning. These are the people who bounce out of bed at 5.30am and feel really awake and alert. By the late afternoon they're waning and they need to go to bed early, so the optimal time for them is different to the optimal time for an owl.

Owls are homozygous for the opposite gene the one that makes people want to stay up until 3am or 4am. That's their most productive awake time, and then they want to sleep until noon. What we've found is that it's much better not to force people into a schedule, it's better for people to figure out what type they are and go with that. But the majority of the population is heterozygous, so they're a combination of those two: they fall somewhere in between.

YOU RESEARCH SLEEP ENGINEERING. WHAT IS THAT?

It's an emerging science based around manipulating the sleep that people get in order to enhance its impact on health and cognition.

We are trying to enhance slow wave sleep, one of the deep phases of sleep, which is characterised by these high amplitude, slow oscillation brain waves, caused by loads of neurons firing in synchrony. When people are in slow wave sleep, we play a little click sound when they're approaching the peak of an oscillation, soft enough that it won't wake

×

“Recent research has shown that sleep is really important for flushing toxins out of the brain”

them up. It enhances the synchronisation of the neurons so you get a higher peak and a deeper trough, which boosts memory consolidation. The method was developed by Hong viet Ngo in Birmingham, and lots of labs around the world are using it. We're trying to optimise it.

Slow wave sleep is one of the things that breaks down with age, so we're trying to enhance the amplitude of those waves to help people get more and deeper slow wave sleep; both healthy young people and older people.

WHAT OTHER PARTS OF SLEEP CAN YOU ENGINEER?

We're also interested in whether sleep can help with processing emotions. There's a theory from Matt Walker at Berkeley which suggests that if you replay memories in REM sleep, you may strengthen the memory but remove the emotional content from it. We have been trying to test this by triggering replay in slow wave and in REM to see what happens to the strength and emotionality of the memory.

We could use this in PTSD, where people have traumatic memories that seem to get more and more traumatic, rather than gradually being forgotten. If we could reduce some of that emotional content just by triggering replay during sleep, that'd be amazing.

PROF PENNY LEWIS

Penny is a psychology professor at Cardiff University. Interview by BBC Science Focus editorial assistant Helen Glenny.

DISCOVER MORE

SQUEEZE EXTRA JUICE OUT OF THE TOPICS IN THIS ISSUE OF *BBC SCIENCE FOCUS* WITH THESE BOOKS, WEBSITES AND SHOWS

Eye opener p10

NASA

Dive deeper into NASA's low boom demos with a load of extra photos and videos from the day.

bit.ly/low_boom

Reality check p34

BBC SOUNDS: ARE TRANSGENDER WOMEN A THREAT TO FEMALE SPORT?

Medical physicist Joanna Harper, who advises the IOC on such issues and is herself a transsexual woman, debates this controversial topic with Dr Nicola Williams, a research scientist who specialises in human biology.

bit.ly/TransgenderSport

Inside a black hole p48

HOW TO SEE A BLACK HOLE: THE UNIVERSE'S GREATEST MYSTERY

This BBC Four programme investigates the Event Horizon Telescope, and how it took a picture of a black hole.

bit.ly/black_hole_spotting

NASA SCIENCE

Visit the black hole section of the NASA website to find out more about black holes and see animations of them in action.

bit.ly/black_hole_NASA

David Veale interview p58

DEPRESSION AND ME

BBC TWO, MAY

Alastair Campbell has suffered from crippling bouts of depression for most of his life. Although

therapy and antidepressant medication make some difference, he wants to know if science can offer him hope of living depression-free.

NADIYA ON ANXIETY

BBC ONE, MAY

Nadiya Hussain was a favourite on *The Great British Bake Off* four years ago. After winning the series, she went on to become a much-loved face on our screens. Yet she's battled with crippling anxiety and panic attacks since childhood. Here, she opens up about what it's like to live with anxiety, and investigates treatments. Check *Radio Times* for details.

Michael Mosley p63

TIM SPECTOR: BREAKFAST – THE MOST IMPORTANT MEAL OF THE DAY?

Tim Spector's blog accompanies the *BMJ*'s large randomised control trial and comes to a pretty happy conclusion, whether you're a proponent of eating breakfast or not.

bit.ly/breakfast_or_not

EFFECT OF BREAKFAST ON WEIGHT AND ENERGY INTAKE: SYSTEMATIC REVIEW AND META-ANALYSIS OF RANDOMISED CONTROLLED TRIALS

Read the journal article that Michael Mosley talks about in this month's column.

bit.ly/breakfast_journal

Rethinking dementia p66

OUR DEMENTIA CHOIR WITH VICKY MCCLURE

BBC ONE, MAY

Vicky McClure investigates what music therapy can do for those living with dementia, by forming a choir where all participants are affected by some sort of dementia.

BBC MUSIC MEMORIES

Evidence shows that music can help people with dementia feel better. This website can help you find songs or theme tunes that could spark powerful memories from earlier in life.

bit.ly/music_memories

THE RESTAURANT THAT MAKES MISTAKES

CHANNEL 4, JUNE

The Restaurant That Makes Mistakes airs on Channel 4 in June. See *Radio Times* for details.

Should medicine be gendered p72

GENDER MEDICINE

BY MAREK GLEZERMAN

(£10.99, DUCKWORTH OVERLOOK)

Leading expert on gender medicine Prof Marek Glezerman's book is an overview of the different ways male and female bodies respond to diseases and treatments – and a call for a more nuanced, gender-sensitive approach.

WHY MEDICINE OFTEN HAS DANGEROUS SIDE EFFECTS FOR WOMEN

In this TED talk, women's health pioneer Dr Alyson McGregor explains how medical research became biased towards men, why this had dangerous consequences for women, and what can be done to start the wheels of change.

bit.ly/medicine_women

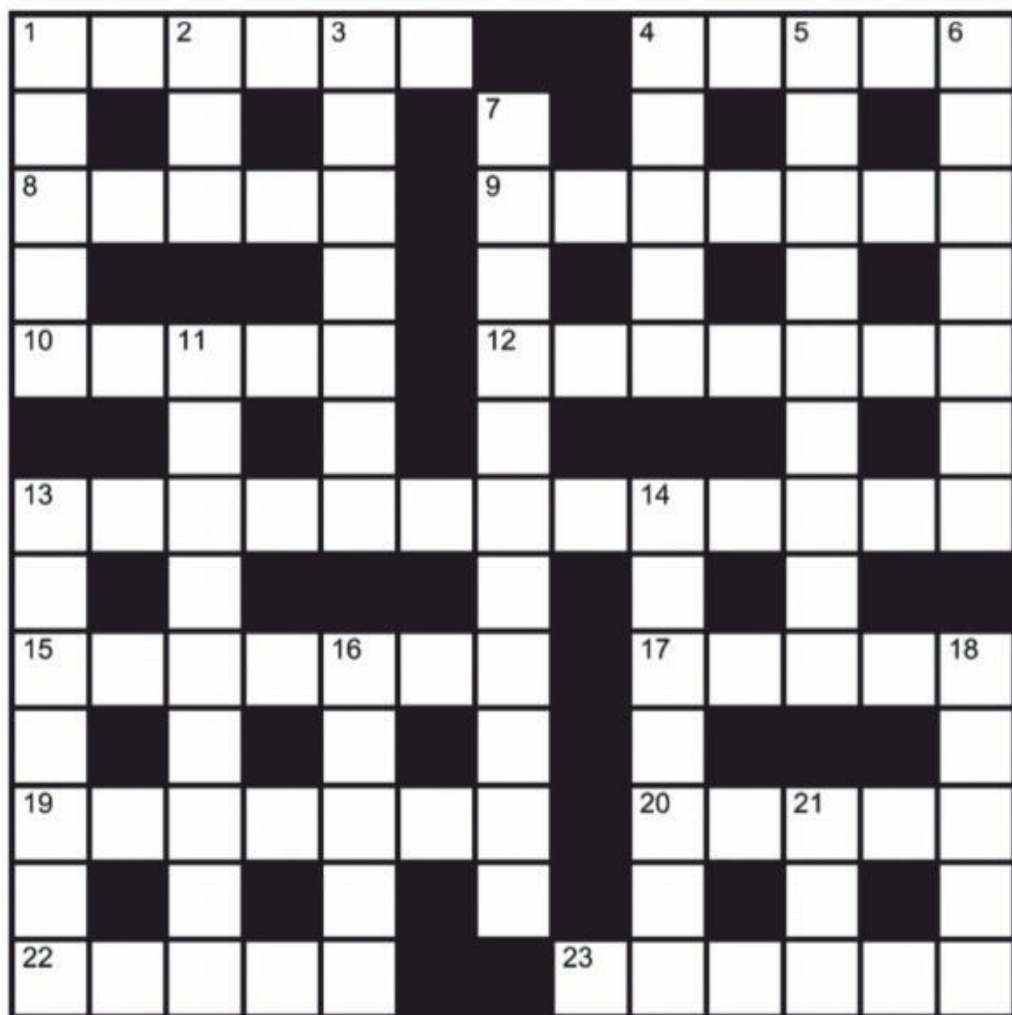
FOR MORE, FOLLOW US



@SCIENCEFOCUS

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

- 1 Previously turn it back into a rodent (6)
- 4 Messenger broke a leg around noon (5)
- 8 Fellow will not finish directions for Trojan (5)
- 9 Chemical-free brain, say, gets one caught (7)
- 10 Cleaner accepts current professorship (5)
- 12 Musical piece cannot omit head of information (7)
- 13 Building material left on slanted shape (8,5)
- 15 Deity just starts cooking tripe (7)
- 17 Idly playing, left in ideal spot (5)
- 19 Spy and traitor always found underground (4,3)
- 20 Initially gullible relative becomes emaciated (5)
- 22 Hiss breaks out about university food (5)
- 23 Wound swirling lines around circle (6)

DOWN

- 1 Had run round cape when necessary (2,3)
- 2 Low-flying bird (3)
- 3 Number on exercise, removing last part of plant (7)
- 4 Old ship, new element (5)
- 5 A lone egg prepared with unknown pedigree (9)
- 6 Produce milk behind schedule, taking turn (7)
- 7 Focus on getting fruit juice (11)
- 11 A harvest, using soil mix from citadel (9)
- 13 Changing pays outside – preserve night attire (7)
- 14 One harbour included pebbles (7)
- 16 Sailor is breaking bones (5)
- 18 The French can produce language (5)
- 21 College merged, expelling Edward (3)

ANSWERS

For the answers, visit bit.ly/BBCFocusCW
Please be aware the website address is case-sensitive.

COVER STORY PAIN-FREE

What can we learn by studying people who feel no pain?



PLUS

THE RISE OF DEEP FAKE

This AI technique can accurately fake people's faces, voices and body movements. Why should we care?

INTERVIEW

RACISM IN SCIENCE

We talk to Angela Saini about her new book, *Superior*, which documents the insidious rise of racism in science.

ON SALE 22 MAY



A SCIENTIST'S GUIDE TO LIFE

EXAM REVISION

EXAM SEASON IS LOOMING
LARGE, BUT WHAT'S THE
BEST WAY TO STUDY?
REVISION EXPERT **NATE
KORNELL** CRACKS OPEN HIS
NOTEBOOKS TO REVEAL ALL



WHAT'S THE BEST WAY TO REVISE?

Human brains don't latch on to things they don't understand, so pay attention to meaning. If all you're doing is trying to memorise facts, you're wasting energy on something your brain is not designed to do. We remember things better if they are contextualised: so understand first, then memorise.

WHAT IF I'M STRUGGLING TO LEARN SOMETHING?

Try and teach it to someone else. It can be a parent, a friend, a dog, anybody really. You can only teach something when you understand it thoroughly and the act of teaching will then help you to remember it. If you find you can't explain something then it will crystallise where the gaps in your knowledge are.

IS IT A GOOD IDEA TO CRAM?

Learning something once and never coming back to it doesn't work. You need to have a break and then revisit what you've learned. The longer the better, so a one week break is better than a one day break, and a 20 minute break is better than a two minute break.

ARE FLASHCARDS USEFUL?

They're okay for certain things like learning foreign vocabulary or molecular structures, but not for things like English

literature. Here, flashcards are not a good way to learn, but there's a lot of evidence to suggest they are effective in review because they can help you to test yourself.

IS HIGHLIGHTING A GOOD IDEA?

Not really. Underlining, highlighting and copying are all passive activities. You learn more when you actively generate knowledge, test yourself, and ask yourself how and why things work.

IS SUMMARISING A USEFUL STRATEGY?

Summarising is good, but be careful. If you take notes from a book and then use those notes for revision, you may have missed certain key points. I recommend always revisiting the original source material at least once, close to the exam.

IS IT OKAY TO LISTEN TO MUSIC WHILE REVISING?

Multitasking is a myth. You can't think about two things at once. The only way you should have music on is if it's not going to distract you. Similarly, don't study in a coffee shop or a busy place where you are likely to lose focus.

WHAT KEY PIECE OF ADVICE WOULD YOU GIVE TO YOUNG PEOPLE REVISING FOR EXAMS?

Make a study plan and stick to it. If you don't, you will procrastinate and end up without enough time. Make sure you understand things, take frequent breaks, revisit what you've learned and be active in your learning.

WHAT ADVICE WOULD YOU GIVE TO THE PARENTS?

Helping your kid with revision or homework can be an extremely emotional thing to do and can lead to a lot of fights. As a parent, your number one goal is to make sure that your kid still wants your help tomorrow. So give them the help they're asking for, rather than the help you think they need. **SF**

NEED TO KNOW...

1

Throw out your
highlighters – they
won't help you.

2

Be active in your
learning, and take
lots of breaks.

3

Music = distracting.

DR NATE KORNELL

Nate is a cognitive psychologist at Williams College, Massachusetts. He researches learning strategies.

**Interviewed by
Dr Helen Pilcher.**



Thank you, Sylvia

Sylvia left a gift in her Will to help conquer Stroke

The first we knew of Sylvia was when we received notification of the gift she'd left us in her Will. Shortly after, a beautiful story of a much-loved woman began to unfurl.

Friends remembered Sylvia's kind-heart and her wish to help others. She spent part of her adult-life caring for her mother, and developed a passion

for medicine. Becoming a medical secretary was her next step and, in the course of her career, she discovered the devastating impact a stroke could have on people and their families. She saw that research and treatment were vastly under-funded, and she decided to remember the Stroke Association in her Will.

Sylvia's gift has helped fund our work to conquer stroke. She's supported research to prevent and treat stroke, and she's helped care for survivors. And that's something you can do too – in the same way.

If you would like to learn more about remembering the Stroke Association in your Will, please get in touch.

**Call 020 75661505 email legacy@stroke.org.uk
or visit stroke.org.uk/legacy**

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Stroke
association



Google

Pixel 3

